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TESIS DOCTORAL

ESSAYS ON MACROECONOMICS AND HOUSING

Autor:

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DEPARTAMENTO DE ECONOMÍA

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Getafe, de de

"...perforé la luz
ahondé el misterio.
Para nada, ahora,
para nada, luego;
humo son mis obras,
cenizas mis hechos.
...Y mi corazón
que se queda en ellos."

Ángel González

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Abstract

My thesis consists of two chapters on Macroeconomics and particularly related to the housing markets. Housing markets have recently played a central role in the evolution of important macroeconomic variables for a set of developed countries. The increasing globalization of the economy and the huge flow of capital between countries interacted with housing markets, having macroeconomic consequences that need to be evaluated.

In Chapter 1 I study the negative correlation between current account balances and housing prices from mid-90s to 2007. This paper studies the effect of financial liberalization during that period on the join behavior of the current account and housing prices in those economies. To this end, I build a life-cycle heterogeneous agents, small open economy model where agents value the consumption of two types of goods: tradable (non-housing) and non-tradable (housing). I calibrate the model to replicate selected aggregate statistics of the US economy and I compute the transition after financial liberalization. Results match some relevant facts: the boom and the bust (after 2007) in the housing market even with remaining low interest rates after the boom, as data show; the increase in the homeownership rate; the simultaneous boom - and bust - in non housing consumption; and the coexistence of borrowing from aboard with a current account deficit along the transition.

In Chapter 2 I quantitatively asses two striking facts of the Spanish economy from a growth accounting perspective: one is the break in the Total Factor Productivity (TFP) growth rate on 1995 with a slowdown tendency since then; and the other is the increase in the relative price of investment. In the light of these facts, I assess quantitatively the contribution of each type of capital in the evolution of measured TFP and growth experience in Spain during the period 1985-2007. I find that almost a 30% of the TFP growth rate slowdown is caused by the increase in the relative price of structures over the period 2001-2007. I also quantify the importance of high technological investment goods on productivity growth. Finally, I assess the ability of a three-sector growth model with a wedge in structures to replicate the growth experience in Spain since 1985.

Resumen

Mi tesis consta de dos captulos en el campo de la macroeconoma y particularmente relacionados con el mercado inmobiliario. El mercado inmobiliario a jugado un papel central en la evolucin de importantes agregados macroeconmicos en un conjunto amplio de pases desarrollados. La creciente globalizacin de los mercados y el enorme flujo de capitales entre pases interacciona con los mercados inmobiliarios dando lugar a importantes consecuencias macroeconmicas que deben ser evaluadas.

En el captulo 1 estudio la correlacin negativa entre los balances por cuenta corriente y los precios de las viviendas desde la mitad de los aos 90 hasta 2007. Este captulo estudia el efecto de la liberalizacin financiera, durante este periodo, en el comportamiento conjunto de la balanza por cuenta corriente y los precios de las viviendas. Para ello, construyo un modelo de economa pequea y abierta con agentes heterogneos y ciclo vital donde los agentes valoran el consumo de dos tipos de bienes: uno transable (todo tipo de consumo menos viviendas) y uno no-transable (viviendas). Calibro el modelo para replicar algunos agregados estadsticos de la economa estadounidense y calculo la transicin del modelo tras la liberalizacin financiera. El modelo es capaz de replicar algunos hechos relevantes: el auge y la cada (despus de 2007) en el mercado inmobiliario, incluso sin revertir el tipo de inters internacional como muestra la evidencia; el incremento de la proporcin de casas en propiedad; el auge y la cada simultnea en el consumo de los otros bienes; y la existencia de endeudamiento de la economa con el exterior y dficit por cuenta corriente durante la transicin del modelo.

En el captulo 2 relaciono cuantitativamente dos particularidades de la economa española desde la perspectiva del "Growth Accounting": el freno en el crecimiento de la productividad total de los factores desde 1995 con una tendencia decreciente desde entonces; y el incremento en el precio relativo de la inversin. Dados estos hechos, cuantifico la contribucin de cada tipo de capital, equipo y estructuras concretamente, en la evolucin de la productividad total de los factores, y mido la capacidad de estos bienes de capital para explicar el crecimiento en España durante el periodo 1985-2007. Lo que encuentro es que casi el 30% del freno en el crecimiento de la productividad total de los factores, desde 2001 hasta 2007, est causado por el aumento en el precio relativo de las estructuras en España. Tambin calculo la importancia de la inversin en nuevas tecnologas en la evolucin del crecimiento de la productividad. Finalmente, compruebo la habilidad de un modelo con tres sectores y con un "wedge" en el sector de las estructuras para simular el crecimiento en España desde 1985.

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Yes... and after so many years it was... a thesis! What can I say...

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[1]Of course, skill still under construction.
[2]Realize I do not say "my" optimum... that may be is not so far...
[3]I am working now in an algorithm making Matlab able to have beers.
[4]...ya sé lo que estáis pensando!

momento, por vuestra paciencia y vuestros consejos. Gracias Lian por ayudarme tanto con tantas cosas, por sentarte siempre a mi lado cada vez que me daba por vencido... por lo menos una vez al día... "no me daré por vencido ni aún vencido..."... Gracias "Tri Tri", porque me salvaste cada vez. Gracias Juan, "Tri Tri", compañero... qué digo compañero... hermano! Gracias a los dos aún, todavía, siempre.

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Para mi padre y mi hermana, por su ejemplo.

Chapter 1

International Interest Rates and Housing Markets

1.1 Introduction

> *"In my view... it is impossible to understand this crisis without a reference to the global imbalances in trade and capital flows that began in the latter half of the 1990s."*
> Ben S. Bernanke (2009)

Current account deficits and housing prices have been positively correlated between the mid-90s and 2007[1]. This period has been characterized by: first, the huge size of housing market booms compared with previous experiences, see for example [3]; and second, the existence of "global imbalances"[2], a particular event of this period of time. In this paper, I argue that these two facts are related and help us to explain the overall dynamics in house prices and consumption in the last 20 years.

Figure 1.1 and Figure 1.2 show the evolution of employment and value added in construction, respectively, for the U.S., Spain, Germany and Japan[3]. Both variables were increasing for Spain and the U.S., and decreasing for Germany and Japan. Hosing prices, in Figure 1.3, follow the same pattern. Figure 1.4 depicts "global imbalances" for these four countries. Summarizing this evidence, countries with current account deficit, Spain and the U.S., experienced a housing market boom and the opposite is true for Japan and Germany.

Most of the literature hinge on preference shocks to the demand for housing to generate a housing boom in the economy, and so account for this positive correlation. See for example

[1]See [82], [2], [3], [44], or [40].

[2]Global imbalances are large and persistent current account deficits run by some countries (e.g. the U.S., Spain) and, simultaneously, current account surpluses in other countries (e.g. Japan, Germany, emerging Asia, some oil exporting countries). See [77].

[3]More countries could be added as it has been documented by others. See [82], [2], [3], [44], or [40] for the same evidence in other OECD countries, non-OECD, or emerging economies.

[83], [40], or [44]. These papers develop a two country model in which one of the economies experiences a positive shock to the demand for housing. The implications are: in one hand, an increase in the expenditure share of housing together with a decrease in non-housing consumption; and, in the other hand, an increase in the international interest rate after the shock. Furthermore, the implications for the housing bust in these economies, that occur after a reversal in the preference shock, would imply a current account surplus, an increase in non-housing consumption, and so a bust in housing prices.

However, these predictions are inconsistent with empirical evidence. As Figure 1.4 shows, current account deficit start to decrease but is still big and negative during the years of the bust. Figure 1.5 shows personal consumption expenditures in the U.S. from the beginning of the 90s to 2010. Non-housing consumption mimicked the housing market boom and bust (and also by a decrease in savings during the boom period, see [3] or [57]) with an annual growth rate of around a 3% over all the period before 2007, and negative growth after 2007.

Another important characteristic over those years is a big increase in the homeownership rate experienced in the economies where housing market boomed. This component of the housing demand means an extensive margin increase in the demand for housing. As it can be seen in Table 1.1, homeownership rates increased in Spain and U.S. and was fairly constant in Japan and Germany. The papers mentioned above do not model the housing tenure decision. The existence of rental markets accounts for the proportion of the economy with no access to borrowing since owned houses can be used as collateral for credit. So, new homeowners will have access to credit.

In this paper I develop a theory of housing boom and bust with the following ingredients: small open economy, to analyze shocks to the international interest rate; life-cycle heterogeneous agents model, with housing tenure decision, in order to account for the extensive margin increase in housing demand; and residential land, modeled following [25] and needed to produce new houses. As [26] shows, land governs housing price dynamics.

Two channels fuel a housing boom in this environment: cheap credit and financial innovation. Both of them as given in the model.

The first channel is a decreasing trend in international interest rates. As Figure 1.6 shows, there was a permanent decrease in interest rates during the period under analysis. The reason for this decrease has been studied in some papers together with the existence of global imbalances. [13] or [73] study, under different hypothesis, the observed fact of low interest rates, and attribute it to the huge savings showed up in the international capital markets during the 90's[4]. As [13] claims, the long-run real interest rate has been steadily declining over the last decade, despite the efforts from central banks to rise interest rates - the "Greenspan's Conundrum". So, I will assume that, because of exogenous reasons from the point of view of developed economies, international interest rates went down over that period.

[4] As the "saving glut" hypothesis ([11]) suggests.

The second channel is institutional. Strong financial innovation (development of housing equity withdrawal, subprime loans, development of securitization), liberalization in mortgage markets, and government support to increase the homeownership rate, implied a decrease in the downpayment requirement to buy a house in the U.S.[5]. Table 1.2 shows evidence for the loan-to-value ratio (LTV) in the U.S. These data refers to LTV ratios for first time home-buyers, the marginal buyers most affected by borrowing constraints. The increase in the LTV ratios was huge over all the period in the U.S..

A housing boom in the model presented in this paper, after a decrease in the interest rate and in the downpayment requirement to buy a house, will imply an increase in housing demand - at both margins -, together with an increase in real house prices and labor in construction. The decrease in the downpayment requirement to buy a house makes possible to some renters to become homeowners. The economy will borrow from abroad because borrowing becomes cheaper and because more expensive houses are used as collateral. This produces a current account deficit. The economy will move labor from the tradable (non-housing) to the non-tradable (housing) sector and will run a trade deficit to fulfill the demand for non-housing consumption. As time goes by, and households start to reach their desired stock of housing, the demand for new houses cools down, decreasing housing prices and labor in construction: a bust in the housing market. Non-housing consumption decreases for two reasons: the economy must pay its debt; and the decrease in housing prices makes homeowners poorer than before. This is consistent with a boom in non-housing consumption and its bust. Moreover, the bust in the economy happens without a reversal in low interest rates. Thus, the model also provides some insights for the bust period based on fundamentals.

Now, I offer a brief review of the literature. [44] argues that preference shocks and a desire for smooth consumption (across goods) can generate a correlation between house prices and capital inflows. He shows that consumption smoothing across tradable (non-housing) goods and non-tradable (housing) goods can lead to a positive correlation between house prices and current account deficits. With an exogenous increase in the home country preference for housing, productive inputs in the home country are reallocated toward housing production, so that housing consumption can rise.

Other papers, like [83] or [40], also rely on higher domestic demand to drive both house prices and capital inflows in the same direction, but they do so through different mechanisms. For example, [83] investigates the ability of borrowing constraints with housing as collateral to account for this negative correlation after the preference shock. [83] also studies other shocks such as an increase in the loan-to-value ratio and productivity shocks.

There are three papers, to the best of my knowledge, similar to this one in adopting a small open economy model and analyzing an interest rate shock. [1] departs from rational expectations in an asset pricing model with learning. They find that real house prices and

[5] See for example [15], [32], or [47].

current account deficits will rise together. On the contrary, my model is perfect foresight and generates a boom and a bust - with no reversal in the interest rate - in housing markets.

[63], and [42] aim to explain housing prices but not the joint behavior of current account balances and housing market variables. [63] is quantitatively-oriented and their model would need a reversal in the interest rate to generate a bust in housing prices. The main difference to the recent paper [42] is that they follow [1] and the bust is explained by a reversal in the beliefs about future interest rates. Another important difference is that they develop a representative agent model without rental markets. In the model presented here I show how, even with rational expectations, the economy would generate a bust in housing markets and this can be consistent with the current account evolution.

There are alternative channels in the literature to generate a housing boom like the interaction between credit market conditions and house prices. For example, in [35], house prices rise in the boom period because of a relaxation of credit constraints and a decline in housing-related transactions costs, both of which reduce risk premia. Conversely, the reversal of the financial market liberalization raises housing risk premia and causes the housing bust.

This paper is also connected to the literature trying to explain the evolution of the homeownership rate. In some papers, for example [15], the decrease in the downpayment requirement in a close economy would increase interest rate with, even, a decrease in the homeownership rate. As I will show, in a small open economy, a decrease of the downpayment can explain the increase in the homeownership rate over this period, even after an increase in housing prices, because international interest rates can not be affected.

The rest of the paper is organized as follows. The model economy is presented in Section 1.2. In Section 1.3, the benchmark model is calibrated to the U.S. economy. Simulations are performed and discussed in Section 1.4, and a brief summary concludes the paper in Section 1.5.

1.2 The Model Economy

I investigate a life-cycle small open economy model populated by heterogeneous agents with three sectors of production. The model strategy follows [43], [28] and [29] in studying different issues of the demand for housing in life-cycle closed economies. The main differences stem from the focus of this paper on the ability of an open economy to run a trade deficit; in the feature that housing consumption is considered as a non tradable good and non housing consumption as a tradable one; and in the existence of three sectors of production: consumption/tradable sector, residential structures sector, and housing/non tradable sector. Housing sector supplies new non tradable houses in the economy by combining residential structures and land where land is a fixed factor of production.

1.2.1 Households

1.2.1.1 Preferences

The economy is populated by overlapping generations of individuals with finite lives and age $j \in \{1, ..., J\}$. The utility function in period t of a new born individual is a CES utility function over consumption of housing services (x_t^j) and non housing consumption goods (c_t^j):

$$\sum_{j=1}^{J} \beta^{j-1} u(c_{t+j-1}^j, x_{t+j-1}^j) = \sum_{j=1}^{J} \beta^{j-1} \frac{\left(((1-\theta)(c_{t+j-1}^j)^{\frac{\varepsilon-1}{\varepsilon}} + \theta(x_{t+j-1}^j)^{\frac{\varepsilon-1}{\varepsilon}})^{\frac{\varepsilon}{\varepsilon-1}}\right)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}$$

where $x_t^j = f_t^j + h_t^j$ is housing services, f_t^j being services coming from renting a house, and h_t^j being housing capital (services coming from owning). Renting and owning are perfect substitutes. I assume that one unit of housing capital generates one unit of services, $x_t^j = h_t^j$. c_t^j is non housing consumption.

1.2.1.2 Housing Capital and Housing Services

An individual must pay in advance at least a minimum downpayment requirement to buy (and thus own) a house. This downpayment requirement is given by a fraction γ of the value of the house. The remaining cost can be financed by borrowing against the house, with $(1-\gamma)$ giving the maximum loan-to-value ratio. Housing capital is subject to some degree of indivisibility. This is modeled by assuming a minimum size of housing investment, $\underline{\text{h}}$.

An individual can rent housing services as an alternative to be a home-owner. Renting housing services has two advantages over owning: first, it allows individuals to consume housing services and thus avoid the downpayment requirement; and second, rent houses are not subject to the same indivisibility as owner-occupied housing.

The price of one unit of housing services in terms of consumption goods is denoted by $r_t^f p_t^h$. Where p_t^h is the price of a house in terms of consumption and r_t^f represents the fraction of that price that an individual has to pay for renting.

Housing capital depreciates at rate δ_h. But rented houses depreciates at a rate δ_f, where $\delta_f > \delta_h$. The different depreciation cost is a result of a moral hazard problem that occurs in rental markets as renters decide on how intensely to utilize a house. The market rate for rental services will incorporate the moral hazard problem and renters have to pay a premium reflecting the additional maintenance cost.

1.2.1.3 Income Dynamics

The life of each individual consists of a working period and a retirement period. These stages are separated by an exogenously given mandatory retirement age, denoted by j^*. Individuals are endowed with one unit of working time in each period of their working lives which they supply inelastically to the both sectors using labor as an input. An age-j individual's unit of working time is transformed into z_j efficiency units of labor. Each unit of effective labor is paid the wage rate ω_t. This specification allows for individuals to differ both across and within generations. At any point in time, the average productivity level is fixed at unity. The measure of the entire population is also normalized at unity.

During the retirement period ($j > j^*$) households receive a retirement pension, b_t, until the end of their lives. The retirement pensions are paid through the social security system and collected from income taxes on labor.

Another source of income comes through individuals asset holdings. Individuals accumulate wealth because life-cycle reasons and to meet the downpayment required to buy a house. Individuals have access to three assets to accumulate wealth: housing, business capital equity, and deposits at financial institutions.

From a household's perspective, deposits at financial institutions and business capital equity are equivalent. A zero-profit condition guarantees that the rates of return on these assets are equalized. As a result, the sum of deposits at financial institutions and business capital equity constitute a single financial asset, denoted a_t^j.

Homeowners also receive rents from the proportion of total land they have and needed to residential development. This proportion of land is exogenously given each period from the point of view of homeowners. And the amount of land they have is a proportion of their housing stock. This issue is explained in more detail in Appendix A.1.

1.2.2 Financial Institutions

Financial institutions receive individuals deposits and make use of it for three activities: finance loans issued to homeowners, purchase residential capital, and borrow/lending in the international capital market. Financial institutions use the same linear technology as homeowners to produce housing services, which they rent out to individuals who do not own a house. Financial institutions borrow from/lend to abroad through the possibility of accessing international capital markets given a fixed interest rate, r_t^*. They have to satisfy the demand for credit from individuals at this interest rate.

Financial institutions, just as homeowners, also receive rents from the amount of land suitable for residential investment they have. This amount is proportional to the stock of housing they buy for renting. See Appendix A.1 for an explanation.

1.2.3 Technology

1.2.3.1 Residential Structures and Consumption Sector

Output by residential structures and the consumption sector is produced using a Cobb-Douglas production technology in each sector:

$$f^i(K_t^i, N_t^i) = A_i(K_t^i)^{\alpha_i}(N_t^i)^{1-\alpha_i}$$

where $i \in \{c, s\}$ refers to a specific sector, with c being consumption sector and s residential structures sector. A_i is a technology parameter, K_t^i is the total amount of business capital used in each sector and N_t^i represents the share of the working population employed in each sector. The capital factor share, α_i, is different for each sector with residential structures sector being more labor intensive, $\alpha_s < \alpha_c$. Each period the stock of business capital depreciates at a rate δ_k. The price of residential structures in terms of the consumption good, which is normalized at unity, is equal to p_t^s.

I assume perfect mobility of factors between sectors such that wages (ω_t) and the price for business capital (r_t^k) is equal in both sectors.

1.2.3.2 Housing Sector

I am following [25] in modeling houses. I assume that a constant acreage of new land suitable for residential investment is sold by homeowners and financial institutions to the firms producing houses. In order to produce new houses residential investment must be combined with land. Homeowners and financial institutions own an amount of the acreage of land proportional to the housing stock they own. Each period one new acreage of land appears and it is sold to firms. This acreage is normalized to one.

Real estate developers combine new residential structures with newly-availabe land to produce new houses according to a Cobb-Douglas technology:

$$f^h(X_t^s, L_t) = (X_t^s)^{1-\phi}(L_t)^{\phi}$$

where X_t^s is the total amount of residential structures used in the production of new houses and L_t represents the amount of land employed. The share of land in the production of new houses is denoted by ϕ. The price of a new house and the price of land, both in terms of consumption good, are represented by p_t^h and p_t^l, respectively.

1.2.4 Government Expenditure

τ_y is a proportional tax rate on labor income and the return on financial assets. Each period the entire proceed from taxation on financial assets is used to finance government expenditures. The entire proceed form taxation on labor income is given back to individuals when they are retired as a pension. The government thus maintains a balanced budget every period.

1.2.5 Household's Decision Problem

Households decide consumption (c_t^j), housing services (x_t^j), the housing capital stock for the next period (h_{t+1}^{j+1}) and the amount of financial assets (a_{t+1}^{j+1}) by solving this problem:

$$v_t^j\left(a_t, h_t; i\right) = \max_{\left\{c_t^j, x_t^j, h_{t+1}^{j+1}, a_{t+1}^{j+1}\right\}} \left\{u(c_t, x_t) + \beta v_{t+1}^{j+1}\left(a_{t+1}, h_{t+1}; i\right)\right\} \tag{1.1}$$

$$s.t. \quad c_t + r_t^f p_t^h f_t + a_{t+1} + p_t^h h_{t+1} \leq$$

$$\leq z^i(1-\tau_y)w_t + b_t^{j>j^*} + (1+(1-\tau_y)r_t^a)a_t + (1-\delta_h)p_t^h h_t + p_t^l l(h_t, h_{t+1}) \tag{1.2}$$

$$a_{t+1} \geq -(1-\gamma_t)p_t^h h_{t+1} \tag{1.3}$$

$$h_t \geq \underline{\mathrm{h}} \; otherwise \; h_t = 0 \tag{1.4}$$

$$x_t^j = f_t^j + h_t^j \tag{1.5}$$

Equation (1.2) is the budget constraint. The term $p_t^l l(h_t, h_{t+1})$ in the budget constraint represents that households hold land in this economy. Households have the proportion of land relative to the amount of their housing capital[6]. Equation (1.3) is the borrowing constraint. Equation (1.4) is a constraint for the minimum house size available in the housing market. Equation (1.5) is the value of housing services.

So, in this environment owning is preferred to renting because of three reasons: first, there is a preference tax treatment for saving in housing rather that in financial assets; second, owning a house allows households to borrow using their housing stock as collateral; and

[6] An explanation of how households hold the proportion of land relative to their homes is offered in Appendix A.1.

third, the depreciation rate of a rented house is bigger that the one for a house owned, as it is explained in section 1.2.1.2..

1.2.6 Financial Institutions' Decision Problem

Financial intermediaries issue loans each period and buy residential capital using the proceeds from deposits they accept and by accessing international capital markets. They have access to the international capital markets through a bond at an international interest rate. They receive payments for rental accommodations, from selling land to the housing sector and receive the interest on loans issued, and pay interests on deposits and on international bonds. The problem of a new financial institution in period t is as follows:

$$\begin{aligned}\Psi\left(F_t, B_t, A_t, K_t\right) &= \max_{\{F_{t+1}, B_{t+1}, A_{t+1}, K_{t+1}\}} \Big\{ r_t^f p_t^h F_t + p_t^l l(F_t) + X_t^A + \\ + r_t^k K_t - X_t^K &- p_t^h X_t^f - X_t^B + \frac{1}{1+r_t}\Psi\left(F_{t+1}, B_{t+1}, A_{t+1}, K_{t+1}\right)\}\end{aligned}$$

$$s.t.\;\; X_t^K + p_t^h X_t^f + X_t^B \leq r_t^f p_t^h F_t + p_t^l l(F_t) + \; X_t^A + r_t^k K_t \tag{1.6}$$

$$X_t^A = A_{t+1} - (1 + r_t^a) A_t$$

$$X_t^B = B_{t+1} - (1 + r_t^*) B_t$$

$$X_t^f = F_{t+1} - (1 - \delta_f) F_t$$

$$X_t^K = K_{t+1} - (1 - \delta_k) K_t$$

where F is the amount of houses rented to households, A is the deposits by households, B is the international borrowing/lending and K is the business capital rented to firms.

From this problem I get the dynamics for the rental price:

$$r_t^f p_t^h = (1 - \phi)[(1 + r_t) p_{t-1}^h - (1 - \delta_f) p_t^h]$$

and the zero-profit condition: $r_t = r_t^* = r_t^a = r_t^k$.

1.2.7 Recursive Competitive Equilibrium

I am interested in the transition of the model since I need to replicate a trade deficit together with borrowing from abroad as it was the case for the U.S. during the period under study. To replicate both facts at the same time it is necessary to evaluate the transition since in a steady state, and without any kind of exogenous growth, a country will be paying debt interest through exports with a small enough international interest rate. For a definition of the steady-state competitive equilibrium see Appendix A.2.

Denote $q = \{a_t, h_t, i\}$, q $\in$ Q.

Definition *A* ***recursive competitive equilibrium*** *for a given government policy, τ_y, down-payment requirement, γ_t, and an age-dependent measure of agents type, $\lambda_j(q)$, is a collection of relative prices $\left\{p_t^h, p_t^s, p_t^l, r_t^f, r_t, w_t\right\}$, a collection of functions for the household problem $\left\{v_t^j(q), c_t^j(q), f_t^j(q), h_t^j(q), a_t^j(q)\right\}$, a value function for financial institutions $\Psi\left(F_t, B_t, A_t, K_t\right)$, and aggregate quantities for the whole economy $\left\{Y_t^c, Y_t^h, Y_t^s, X_t^s, L_t, K_t^c, K_t^s, N_t^c, N_t^s, F_t, B_t, A_t\right\}$ such that:*

1. *Inputs are priced competitively every period.*
2. *Given τ_y, γ_t and prices, the functions $\left\{v_t^j(q), c_t^j(q), f_t^j(q), h_t^j(q), a_t^j(q)\right\}$ solve the dynamic program from the household problem.*
3. *Given prices and the function $\Psi\left(F_t, B_t, A_t, K_t\right)$, $\{F_{t+1}, B_{t+1}, A_{t+1}, K_{t+1}\}$, solves the financial institutions' problem.*
4. *Individual and aggregate decisions are consistent: $C_t = \sum_{j=1}^J \int_Q c_t^j d\lambda_j(q)$, $H_t = \sum_{j=1}^J \int_Q h_t^j d\lambda_j(q)$, $F_t = \sum_{j=1}^J \int_Q f_t^j d\lambda_j(q)$, $A_t = \sum_{j=1}^J \int_Q a_t^j d\lambda_j(q)$.*
5. *The government maintains a balanced budget every period:*
$$G_t + b_t = \sum_{j=1}^{J} \int_Q \left[\tau_y w z_t^j + \tau_y r a_t^j\right] d\lambda_j(q)$$
where $b_t = \sum_{j=1}^J \int_Q b_t^j d\lambda_j(q) = \tau_y w_t \overline{N}_t$.
6. *Labor market clears every period: $N_t^c + N_t^s = \overline{N}_t$.*
7. *Capital market clears every period: $K_t^c + K_t^s = K_t$.*
8. *Land market clears every period: $L_t = \overline{L}_t$.*
9. *Residential structures market clears every period: $X_t^s = Y_t^s$.*

10. *Housing market clears every period:*

$$Y_t^h = X_t^h + X_t^f$$

where $X_t^h = H_{t+1} - (1 - \delta_h)H_t$.

11. *Trade balance is determined every period:*

$$TB_t = Y_t^c - C_t - X_t^k - G_t$$

where $X_t^k = K_{t+1} - (1 - \delta_k)K_t$.

12. *Net foreign asset position is determined every period:*

$$B_{t+1} = TB_t + (1 + r_t^*)B_t$$

1.2.7.1 Characterization

The price for structures becomes:

$$p_t^s = \frac{A_c}{A_s} \frac{\alpha_c^{\alpha_c}(1-\alpha_c)^{1-\alpha_c}}{\alpha_s^{\alpha_s}(1-\alpha_s)^{1-\alpha_s}} \left(\frac{w_t}{r_t + \delta_k}\right)^{\alpha_c - \alpha_s}$$

From this equation, after a shock to the international interest rate, the effect over the price of structures depends on the difference between the capital shares of the consumption sector and the residential structures sector ($\alpha_c - \alpha_s$). As it will be shown in the calibration section, it is true for the U.S. economy that the residential structures sector is more labor intensive than the consumption sector. This means that after an exogenous decrease in the international interest rate, wages will increase, since labor becomes relatively scarce, and as a consequence of the bigger capital share in the consumption sector, this decrease in the international interest rate will imply an increase in the price of residential structures.

Housing prices become:

$$p_{ht} = \frac{p_{st}^{1-\phi} p_{lt}^{\phi}}{(1-\phi)^{1-\phi}\, \phi^{\phi}}$$

From this equation for housing prices it can be inferred that after a positive shock (interest rate and downpayment requirement) to the demand for housing, an increase in the demand for land will occur, and, given the fixed supply of land in the economy, the price of land will increase. Both the increase in the price of structures and the increase in the price for land will increase housing prices in this model.

1.3 Calibration

The benchmark model is calibrated for the U.S. economy as a closed economy in my initial steady state. After the shocks I allow the economy to have access to international borrowing and lending and to have a trade balance different from zero. Thus, U.S. economy becomes a small open economy during the transition. I present the calibration of my benchmark economy in the following order: demographics and labor income distribution, technology, and preferences and market arrangements.

The calibration involves parameters associated with preferences $(\beta, \theta, \sigma, \varepsilon)$, the income tax rate (τ_y) as well as the downpayment fraction (γ), and parameters associated with technology $(A_c, A_c, \alpha_c, \alpha_s, \phi)$ as well as depreciation rates $(\delta_h, \delta_f, \delta_k)$. The distribution of productivity levels within and across generations also needs to be specified. The U.S. in 1994 is the target for the experiment.

1.3.1 Demographics and Labor Income Distribution

A model period is taken to correspond to one full year. Individuals are assumed to live for $J = 60$ model periods. One can think of members of a new generation as being born at real-life age 24 (model period one) and having an expected age of death of 83 years (60 model periods). The retirement age is set at age 63 (model period 40).

The distribution of productivity levels directly controls the labor endowment process and thus labor income. I calibrate this process using the CPS survey for 1994. More precisely, I calculate the mean labor income for each quintile in the data at each age and assign this value directly to the five individuals making up the population in the model. The normalized labor income profile for each individual, each representing a quintile, is shown in Figure 1.7.

The retirement age is obtained using the same data. The median labor income for the entire population becomes zero at age 63 (model age 40). When individuals become retired they start to draw their pension collected from taxes on labor income over their working life.

1.3.2 Technology

I need to construct measures of output by the consumption sector and by the residential sector, capital, the stock of houses and their investment counterparts $(Y^c, p^h Y^h, K, p^h(H + F), X^k, p^h(X^h + X^f))$. I use data from the National Income and Product Accounts (henceforth NIPA) and the Fixed Assets Tables (henceforth FAT), both from the Bureau of Economic Analysis. I define capital as the sum of non-residential private fixed assets plus the stock of inventories plus consumer durables. Investment in capital, X^k, is defined accordingly[7]. $p^h(H+F)$ is private residential stock in the data and $p^h(X^h+X^f)$ is private residential investment. I define output in consumption sector as labor income plus income from non-residential capital, $Y^c = F(K^c, N^c) = wN^c + rK^c = C + I^k + G$, output in the residential sector is labor income plus income from non-residential capital plus land income $Y^h = F(X^s, L^c) = wN^s + rK^s + p^l L = I^h + I^f$, and total output is the sum of output from each final sector, $Y = Y^c + p^h Y^h$, or measured GDP minus imputed housing services[8]. I do not make any imputation to output for government owned capital since our focus is on privately held wealth.

The business capital share for residential structures sector I use is $\alpha_s = 0.132$, and I take this from [25]. I also take from [25] the land share in new housing, $\phi = 0.106$. Calculations in [25] are in the same context as the model presented here.

I proceed as [21] and calculate the implied share of capital in output in the consumption sector, which is $\alpha_c = 0.26$. The capital- output ratio (K/Y) is 1.66 and the housing-output ratio $((p^h(H+F))/Y)$ is 1.07[9]. I set the depreciation rate of capital, δ_k, so that it matches the investment to capital ratio in NIPA, $\delta_k = 0.12$. The implied steady state interest rate is 3.4 percent.

The value of the implied capital share in the consumption sector may seem low, but it is not very different from typical values in the literature when given as a function of GDP instead of output. GDP is output plus the imputed value of housing services: $GDP = Y + (r+\delta_h)p^h H + r^f p^h F$. The capital-GDP ratio (K/GDP) is 1.53, the housing-GDP ratio $(Kp^h(H+F))/GDP$ is 0.98, and the aggregate ratio $(K + p^h(H+F))/GDP$ is 2.51. The resulting share of capital income to GDP is 31.52 percent, just slightly lower than that estimated by Prescott (1986).

The technology level for consumption sector (A_c) and residential structures sector (A_s) is such that $A_s < A_c$ as suggested by evidence. I set $A_c = 2$ and $A_s = 0.9$ to replicate the aggregate ratio $(K + p^h(H+F))/GDP = 2.51$ and the housing-output ratio of 1.07.

The minimum house size is such that the homeownership rate in the economy is 64 percent[10]. With minimum size equal to 1.4775 for owner-occupied houses and given a downpayment fraction of 20 percent, the model replicates the homeownership rate for the U.S..

I borrow the values for the depreciation rates from [29], given that my benchmark economy is a closed economy and those values are consistent with general equilibrium. The values are

[7] I include net exports in my measure of capital investment since the benchmark economy is a closed economy.

[8] C is output in the consumption sector minus the sum of investment in physical capital and government expenditures.

[9] All figures I report are averages in NIPA/FAT for the sample period 1954-1994.

[10] Data from United States Statistical Abstract and Housing Vacancies and Homeownership (CPS/HVS) for 1994.

$\delta_h = 0.0424$, $\delta_f = 0.0483$, and $\delta_k = 0.12$. I also borrow the income tax rate τ_y from [28] with a value of 0.2.

1.3.3 Preferences and Market Arrangements

The value of the discount factor is chosen to make the capital-output ratio equal to 1.66. It should be noted that capital refers to the total amount of capital, which includes housing and business capital, and that output corresponds to the sum of output goods and the value of housing services. The discount factor which achieves the desired capital-output ratio is 0.9757.

The share of housing services in total expenditures is controlled by θ. I set this parameter in order to replicate the ratio $p^h(H+F)/C$ in the U.S. economy. In the data this ratio is equal to 1.4, and the θ that matches it is 0.0765. Whit this value for θ I also replicate the ratio $p^h(H+F)/GDP$ in the U.S. of 0.98.

I set the risk aversion parameter in the utility function at $\sigma = 0.5$, since this is the value usually employed in business cycle literature. This parameter determines the inter-temporal elasticity of substitution. The last parameter referred to preferences is ε. This value determines the intra-temporal elasticity of substitution between consumption goods and housing services. Usually the literature on housing in closed economies uses a Cobb-Douglas utility function in order to reconcile the fact that different estimations of this parameter have a lot of variability in the literature, from above and to below one[11]. Recent studies that rely on structural analysis in order to estimate those parameters suggest that housing services and consumption goods are complements. See for example [6] or [69]. So I set this parameter at a value smaller than one (and conduct some sensitivity analysis) in order to see how this value affect the results. I choose a conservative value of $\varepsilon = 0.9$, as in [44].

I require a minimum downpayment of 20 percent. Thus individuals can borrow up to 80 percent of the value of the house. While in reality households may be able to acquire houses with lower downpayment, it is also the case that these households face higher marginal borrowing costs (including a higher interest rate and the purchase of mortgage insurance). To keep the model tractable, the downpayment parameter is the same for all consumers and the borrowing rate is not a function of γ.

All parameter values for the benchmark calibration are summarized in Table 1.3.

[11] See [39] for a discussion.

1.4 Results

1.4.1 The Benchmark Economy

The typical behavior of individuals in the initial steady state can be broken down into three categories of individuals: poor and lower middle class (first and second quintile), middle-class (third quintile) and upper-middle class (fourth and fifth quintiles). The behavior of poor and lower middle-class individuals is quite simple: they hardly own their home, they set up cooperatives[12] in which a small proportion of households (around 17-20% in the first quintile and 50-55% in the second) own the house in which they live, and always consume a small amount of housing services. Middle-class individuals initially consume small amounts of housing services and consumption in order to save enough to eventually become homeowners. When they become homeowners, at age 33, they move into the smallest possible house. At that time, these individuals are constrained both by the downpayment and the minimum house size constraints. During their first few years as homeowners, they use all their extra income to increase consumption and pay down their mortgage. As they get wealthier, they eventually move into bigger houses.

The consumption level of young upper middle-class individuals is also constrained as they accumulate wealth to cover the downpayment on a house. After 2-3 years accumulating wealth, at age 29-30, they move into the largest house their downpayment can afford. Unlike lower middle-class individuals, they are not constrained by the minimum house size: they keep living in the largest house their downpayment can afford for 2-3 years. After this constrained period, they increase housing services and consumption.

All individuals accumulate assets during their productive years which they deplete to provide for consumption once retired instead of having a retirement pension. Homeowners thus partially revert to debt financing their house (rather than holding the entire asset as equity) in order to consume goods as well as housing services during the last few periods of their life. Without uncertainty, all individuals die with zero net worth.

1.4.2 Experiment

I evaluate the behavior of the model after a permanent and unanticipated shock to the international interest rate and to the downpayment requirement to buy a house. I want to evaluate the joint effect of these two shocks and identify the contribution of each one separately. Since the model is calibrated to the U.S. economy the size of the shocks will be taken from data for this country. As I explained before, I will evaluate the transition of the model after both shocks.

[12] Explained in Appendix A.1.

The initial steady state will be the closed economy case with trade balance and borrowing from abroad equal to zero. I will compute a long run case with the final values for the international interest rate and for the downpayment requirement in which the country will be borrowing from abroad and paying debt interests by exporting goods, so a sustainable debt. Then I will compute the transition between these two points and look at different variables. A detailed explanation of the computational procedure is in Appendix A.1.

I set the shock for the international interest rate from the value obtained in the initial steady state to 0.6 percentage points smaller. This value is the median of the annual decreases in the long run interest rate on government bond in U.S. since 1991 to 2007. I choose the median instead of the mean of the annual decreases because of the high variability over all the period in this interest rate. This value is taken from the data showed in Figure 1.6. So, my quantitative targets in this experiment will be the median of the changes in variables over all the period. Of course, it is work in progress to see how the model respond to a decrease over all the years but the main insights of the model should not change. Moreover, it is easier to understand the mechanisms of the model with a once and for all change in the exogenous variables.

I set the shock to the downpayment requirement in the same way, that is the median of its annual decrease over all the period. This will imply a fall from its value in the initial steady state of 0.2 to a 0.18. The size of these magnitude are in line with the evidence presented in the introduction.

1.4.2.1 The Joint Effect

In this section I investigate the effect of both shocks at the same time. Figure 1.8 shows both shocks, implemented once and for all.

Both shocks drive up the demand for housing services - at both margins. The interest rate decrease makes, in one hand, mortgages[13] cheaper, and, in other hand, more attractive to save in a house than in financial assets. The downpayment shock makes it easier to access to the housing market for households that would rent otherwise, and makes it possible to buy bigger houses for previous owners.

The first result is plotted in Figure 1.9 to show that the model is consistent with the evolution of housing prices and the current account balance. The model generates a housing prices boom in the period of the shock together with a current account deficit. The increase in housing prices accounts for 80% of the median annual increase in housing prices for the period under study. The model exaggerates the current account deficit (around a 10% of the GDP) in the period of the boom since there is no adjustment cost and all variables move freely in the period of the shock.

[13]The model presented can be rewritten to include a simple mortgage into the definition of financial assets. See [43].

Figure 1.10 shows that the model is able to replicate the behavior of the extensive margin increase after both shocks even with an increase in housing prices. The increase in the homeownership rate in this period is around a 1% increase in line with the annual increase in the homeownership for the U.S. economy since 1994. The housing stock increases in the period of he boom and it is still increasing, at a smaller rate, after some periods. The increase in housing prices raises the value of the collateral during the boom, and so, there is an increase in non-housing consumption because of two reasons: the increase in the value of the collateral and the decrease in the interest rate. As it can be seen, the increase in non-housing consumption is consistent with the annual median increase in personal consumption expenditures for the U.S. economy, around a 3%. The overshooting in non housing consumption is related with the small open economy assumption, but the quantitative response in the non housing consumption boom period is determined also by the increase in the value of the collateral. Thus, after the boom in non-housing consumption there is a bust because of two reasons: the debt must be paid, since it is a small open economy borrowing from abroad in the period of the boom; and because of a decrease in the value of the collateral, since housing prices start to decrease after the boom in the first period.

Figure 1.11 represent the ability of an open economy to replicate what is observed in data. An open economy moves resources from the tradable to the non-tradable sector (labor in construction), thus increasing the production of the non-tradable good (housing production). Since there is an increase in the demand for non-housing consumption, running a trade deficit allows the economy to satisfy this demand. [44] points out this result, but here the reason is the negative shock to the international interest rates and no a positive shock to the demand for housing.

In Figure 1.12 I show the decomposition of housing prices together with the rent-to-price ratio. As it can be seen, the price of structures increases once and for all. This is because a converse result of the Stolper-Samuelson theorem. After the decrease in the interest rate, the capital-labor ratio of the economy increases, causing wages to increase. Since structures are more labor intensive than the consumption sector, this increase in wages makes the price of structures increase. Land prices increase a lot in the period of the shock, and then start to decrease. The pressure on land is bigger in the period of the shock and then decreases gradually over time. This effect is what governs the evolution of land prices and is what move housing prices following the same pattern. The existence of land modeled as in [26] make it possible for housing prices to be demand driven.

Rent-to-price ratio decreases in the period of the boom and then increases following the non-arbitrage condition of the financial institutions. This evolution of the rent-to-price ratio is consistent with what we observe in the data for this ratio during the boom period. However, during the bust this price goes in the wrong direction.

It is important to note that the bust happens without a reversal in the interest rates after the boom period, but also without a reversal in the downpayment requirement. The reversal in the downpayment requirement would worsen the bust in housing market variables. If there is evidence for the interest rates to stay low after the bust period, it is also true that there is evidence of a reversal in the downpayment requirement to buy a house.

Figure 1.13 shows what happens to all the housing variables together and how the model is able to generate a boom and a bust in the housing market. The housing stock shows the biggest increase in the period of the shock, so increasing the pressure on land and increasing housing prices, the economy moves labor to the production of structures in this period. After this boom period, the pressure on land starts to decrease, thus decreasing housing prices and the production of new houses in the economy. Then, the bust happens. This is the mechanism behind the overshooting in housing prices. The evolution of Housing Production, i.e. investment in housing, is the one that puts pressure on land prices replicating the overshooting in this variable. For this reason housing prices drop to a level above the initial steady state. The investment in housing, in a steady state with lower interest rate and downpayment, is bigger than the investment in housing in the initial steady state. Once all new houses have been built, the depreciation of a bigger stock of housing must be built in a plot of land of an equal size each period.

Figure 1.14 shows how, during the bust period, there is a reversal in the trend of the current account but still a current account deficit. In the period of the shock, the model exaggerates the current account deficit but a big deficit (around 2.5% of GDP) still exists in the first period of the bust and during some periods ahead. The net foreign asset position is deteriorating until the final steady state is reached. Moreover, and consistent with the evidence for this period, the bust happens without a reversal in interest rates.

1.5 Conclusions

In this paper, I have studied the transition in a life-cycle heterogeneous agents small open economy model in which the economy goes from an initial steady state to a final one with low interest rates and low downpayment requirement to buy a house. The model is able to replicate qualitatively the evolution of the U.S. economy during the housing boom experienced in the 90s and to 2007, and also (qualitatively) the bust period after 2007.

The model is able to replicate some important facts of the U.S. economy such as the boom in non-housing consumption, the increase in the extensive margin demand for housing in this period, and the current account deficit together with borrowing from abroad along the transition. Two characteristics of the model contributes to its successful in replicating those facts: one is that demand drives housing prices in the economy, and the other is the life-cycle heterogeneous agents structure. Households want to build up their desired stock of housing and this generates the pressure over housing prices. The bust in housing prices happens when the pressure of the demand decreases. The degree of heterogeneity in the economy make some households able to access to the housing market because of the decrease in the downpayment requirement to buy a house. The decreasing interest rates allows households to get cheaper credit for consumption with the increasing market value of their homes.

The implication of these assumptions is a surge of housing and non-housing consumption at the beginning of the transition. Everybody would want an expensive house to get access to credit. When the the pressure of new houses over land decreases, the value of houses becomes down, debts must be paid, and the bust happens in the economy. Therefore, current account deficit decreases but remains negative with low interest rates as this seems to be the case for the U.S. after the bust in housing markets. It is true that the downpayment requirement in the U.S. after the bust in housing markets became higher but given the intuition of the model this positive shock to the downpayment requirement would imply a bigger bust in the economy presented here even with low interest rates.

The small open economy assumption allows to have together a decreasing downpayment and an increasing homeownership rate in the economy. In a closed economy, like the one of [15], a decreasing downpayment requirement would increase the demand for credit increasing the interest rate in the economy. This could even decrease the homeownership rate of the economy. As I showed here, given international interest rates, this shock would increase homeownership rate even after the increase in housing prices.

Quantitatively the model is able to explain almost a 80% of the median annual increase in housing prices over the period under study. The model show quantitative responses in line with data for the homeownership rate, the decrease in the rent-to-price ratio, the increase of labor in the housing market, and, importantly, the evolution of the current account of the U.S. economy during the bust period in spite of an overestimation in the deficit during the boom period since the model lacks of any kind of adjustment cost.

At the moment, I am developing the paper in three directions. First, I want to analyze each shock separately. A decrease in the interest rate seems to be quantitatively more important than the shock to the downpayment requirement. This result is in line with [63]. But a decrease in the downpayment is necessary to explain the extensive margin increase in the demand for housing. Also, sensitivity analysis in the intratemporal elasticity of substitution (ε) will be carried out. Second, I am studying the welfare implications for different groups of agents (renters, new homeowners, and previous homeowners). There is a concern on the inequality consequences of the crises, and it is important to understand the dynamics of inequality over the cycle. And third, I am analyzing the role of different tax systems. In the current version of the model, imputed rents are not taxed and mortgage interest payments are fully deductible. Evidence over this period shows a clear preference tax treatment for housing capital. Different tax policies could be evaluated along the transition. Building on [28], I am extending the paper to account for this dimension.

The model presented here would be an interesting model to be used in other contexts. Evidence suggests that variations in international interest rates cause similar movements in developing economies. Further research would be why countries like Japan or Germany did not experienced a housing boom over this period since interest rates also decreased in those countries. I think that a two country version of this model could help to answer this question addressing important potential explanations to this pattern, as differences in TFP growth or real exchange rates, as [13] suggests. But this is left to further research.

Table 1.1: Homeownership Rates.

	Germany	Japan	Spain	United States
1990	39	61	76	63.9
2000	41	60	81.34	67.4
2006	40	60.9	85.3	68.8

Source: OECD.

Table 1.2: Loan to Value Ratio (LTV).

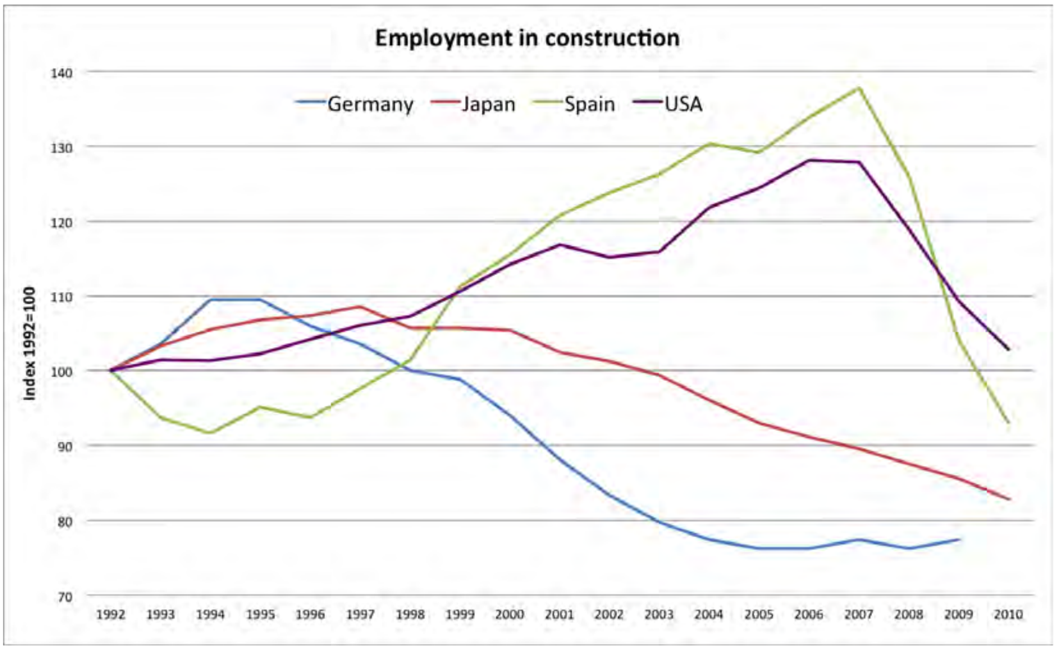
Year	LTV
1995	78.4
1998	86.2
2003	94.4

Source: [33].

Table 1.3: Model Parameters.

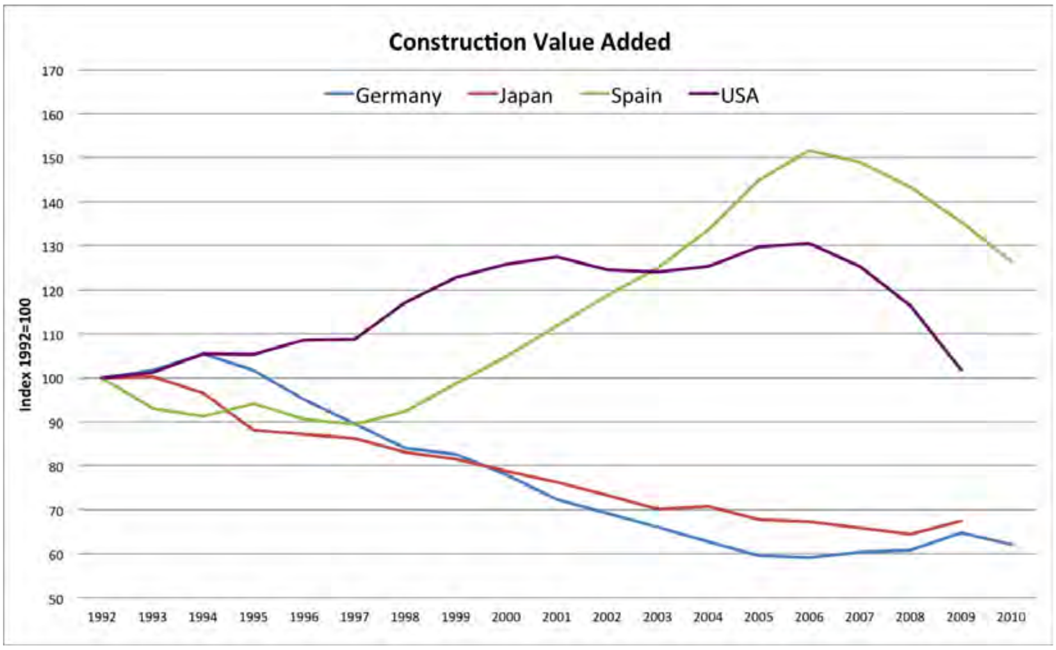
Parameter	Value
β	0.9757
θ	0.0765
σ	0.5
ε	0.9
γ	0.2
$\underline{\mathrm{h}}$	1.4775
A_c	2
A_s	0.9
α_c	0.2616
α_s	0.132
ϕ	0.106
δ_k	0.117
δ_h	0.0424
δ_f	0.0483
τ_y	0.2

Figure 1.1: Employment in Construction.



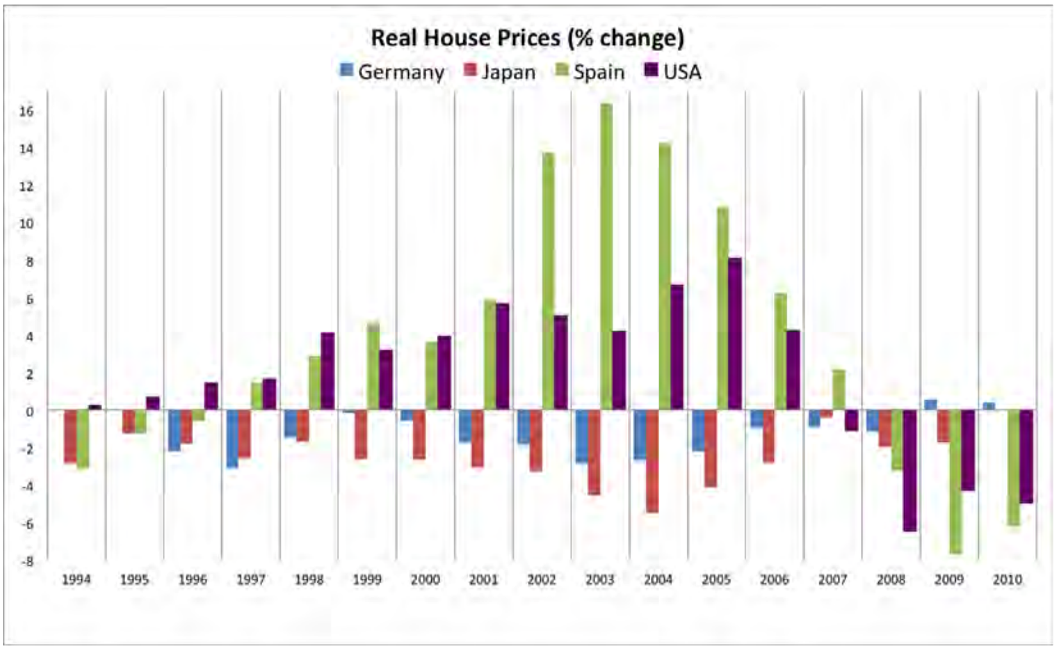
Source: OECD.

Figure 1.2: Construction Value Added.



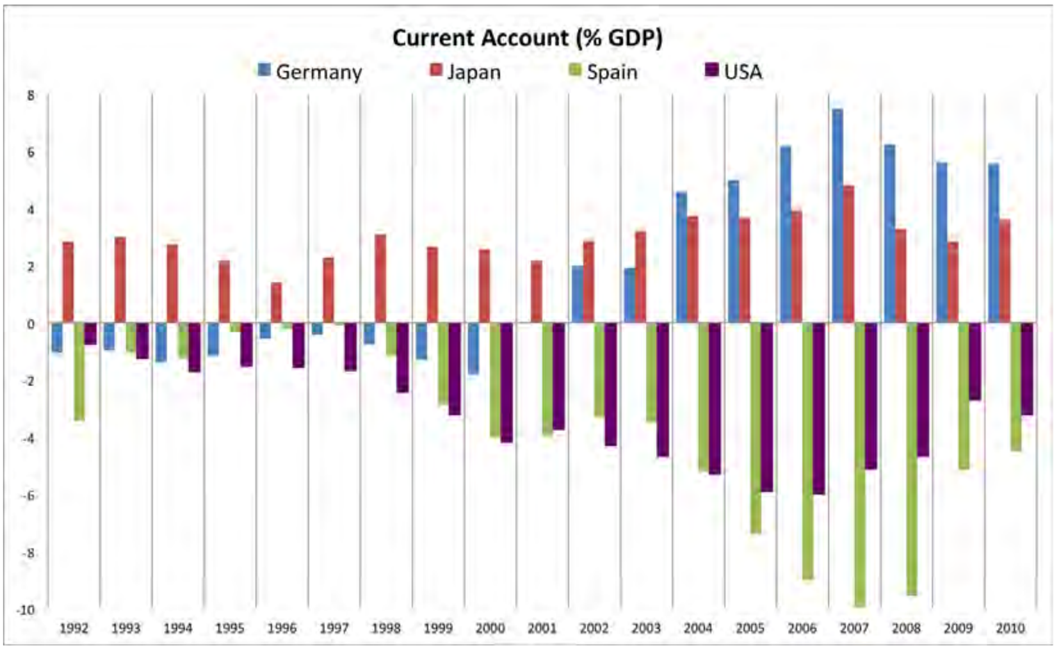
Source: OECD.

FIGURE 1.3: Real House Prices (% Change).



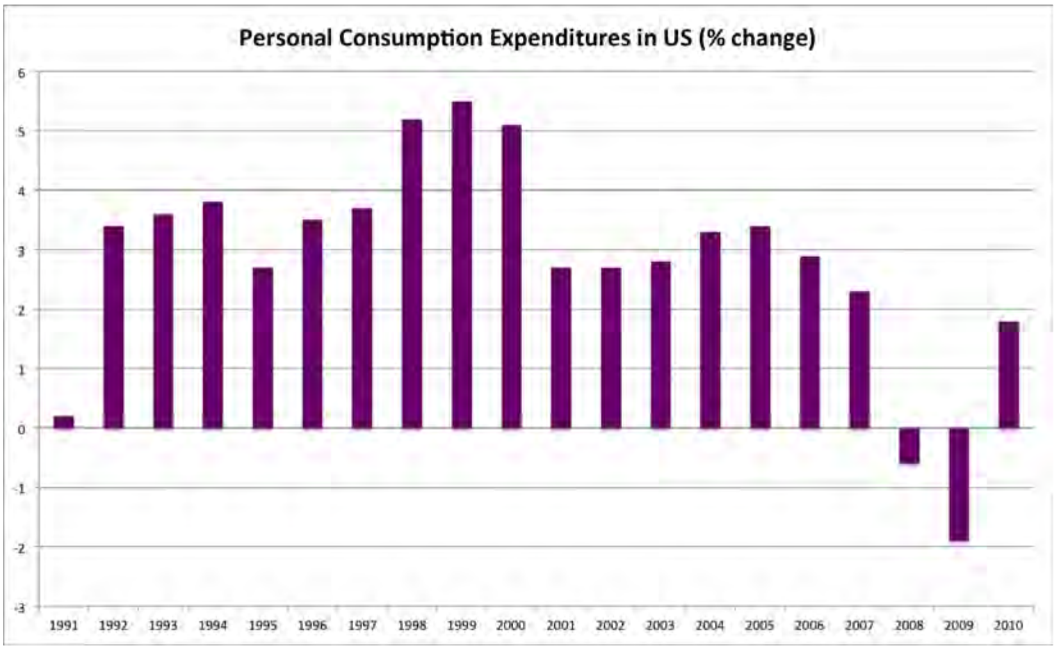
Source: OECD.

FIGURE 1.4: Current Account (% GDP).



Source: OECD.

FIGURE 1.5: Personal Consumption Expenditures (% Change).

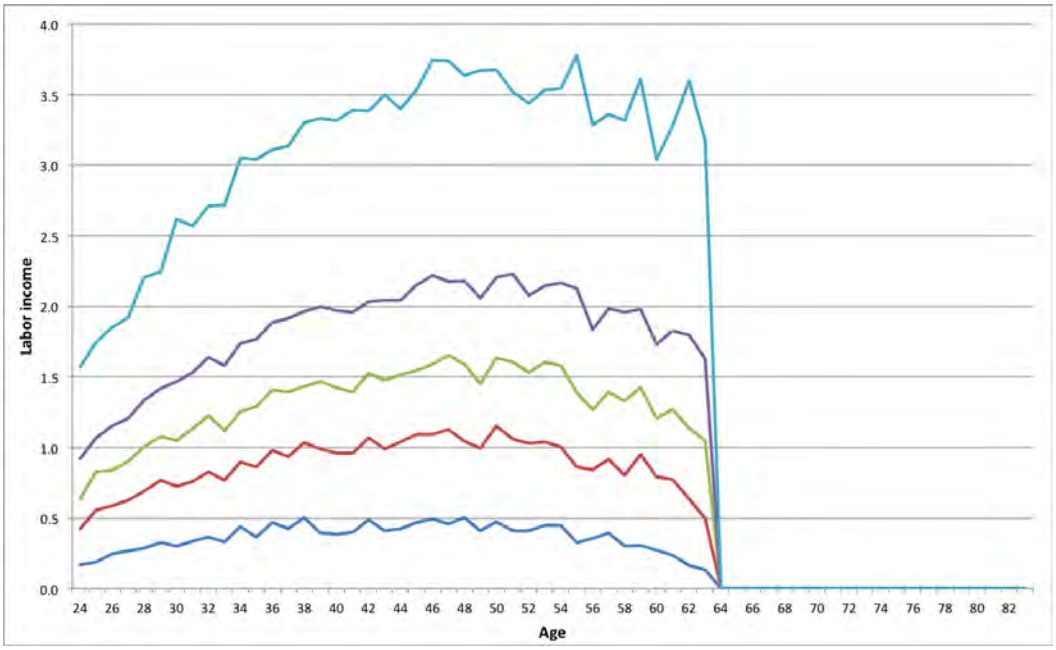


Source: NIPA.

FIGURE 1.6: Interest Rates.

Source: OECD.

Figure 1.7: Labor Income.



Labor income process for each quintile.
Source: Current Population Survey (CPS).

FIGURE 1.8: Interest Rate and Downpayment Shock.

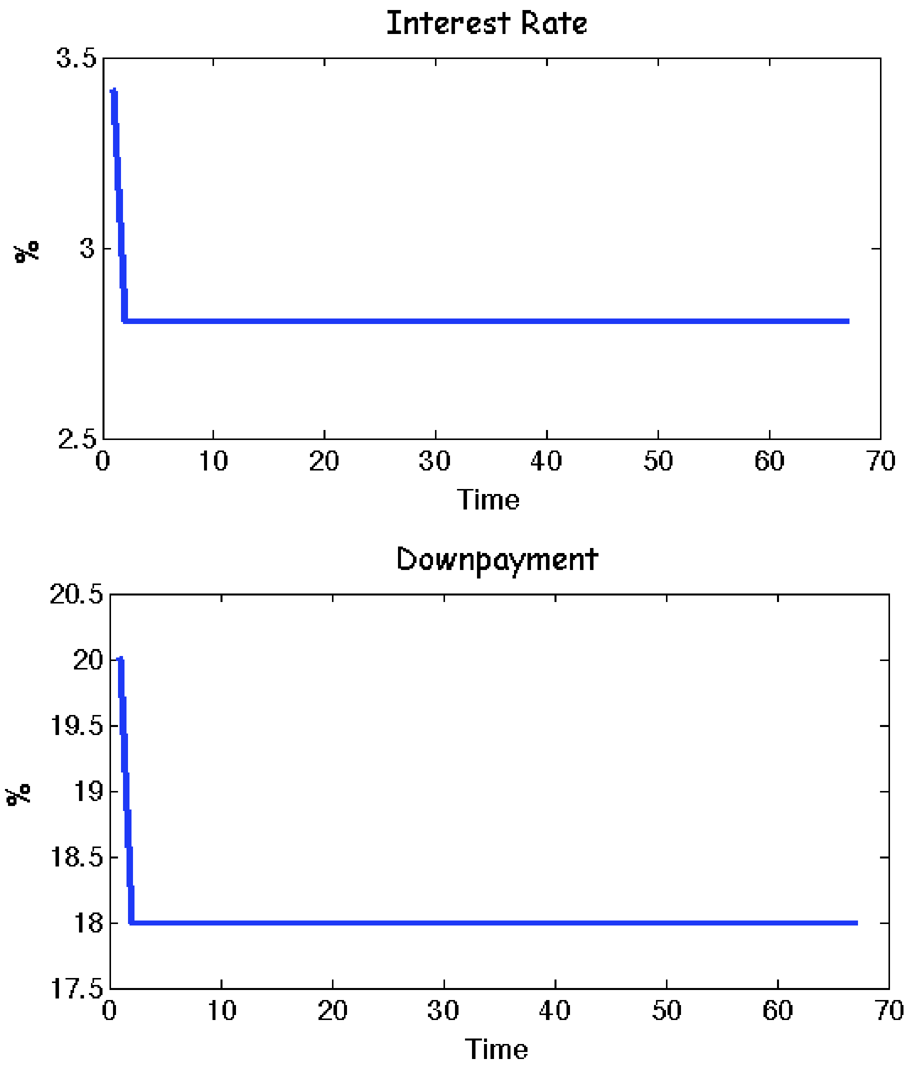


FIGURE 1.9: Negative Correlation between House Prices and Current Account Balance.

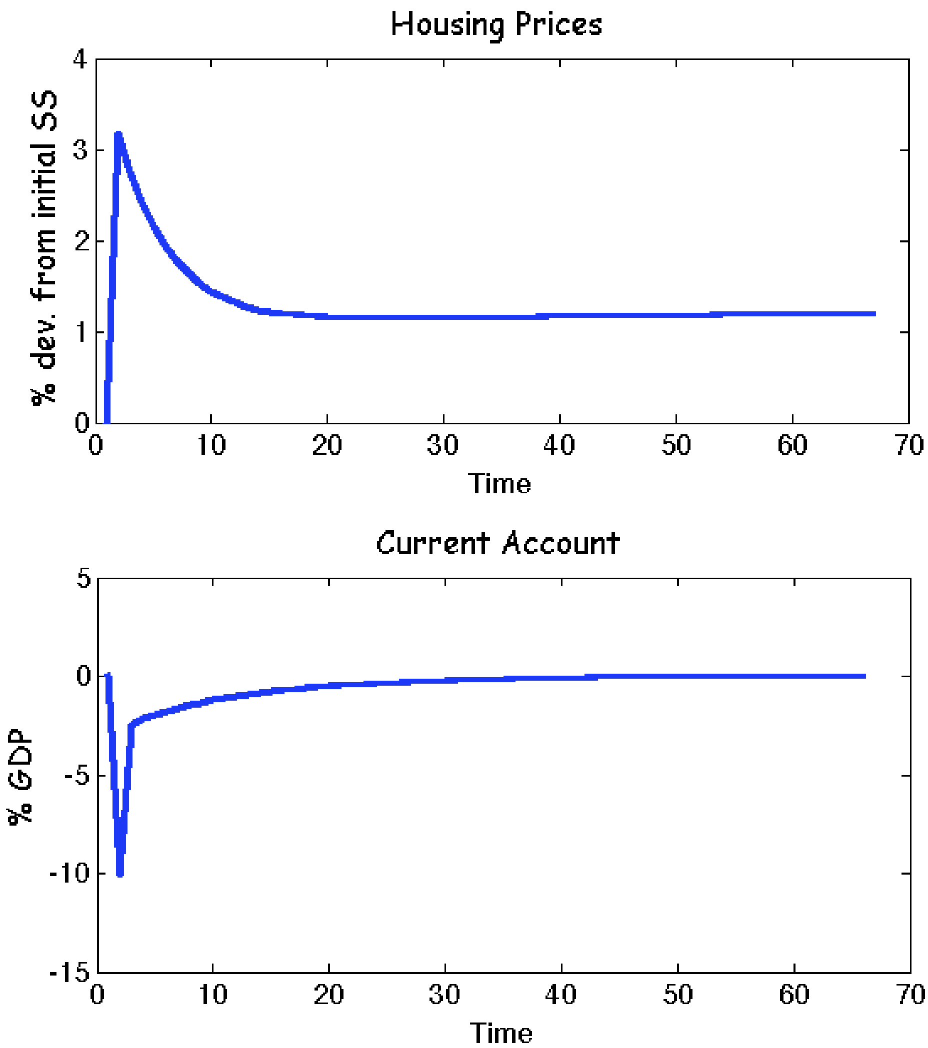


FIGURE 1.10: Extensive Margin and Non-Housing Consumption.

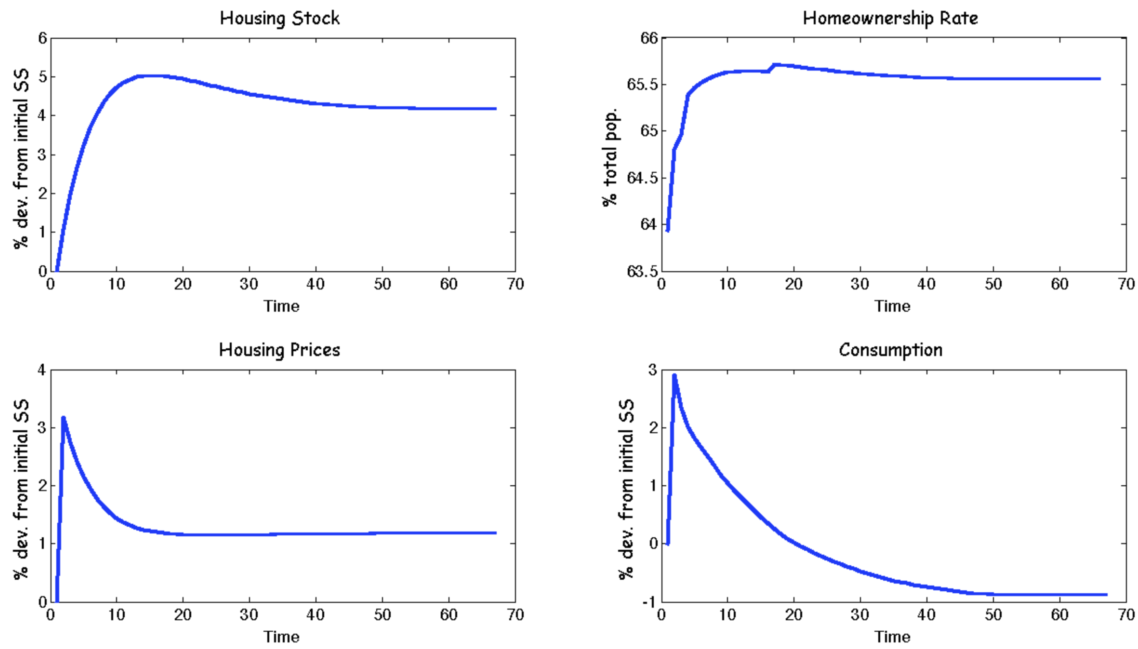


FIGURE 1.11: International Interest Rate Shock and the Housing Boom.

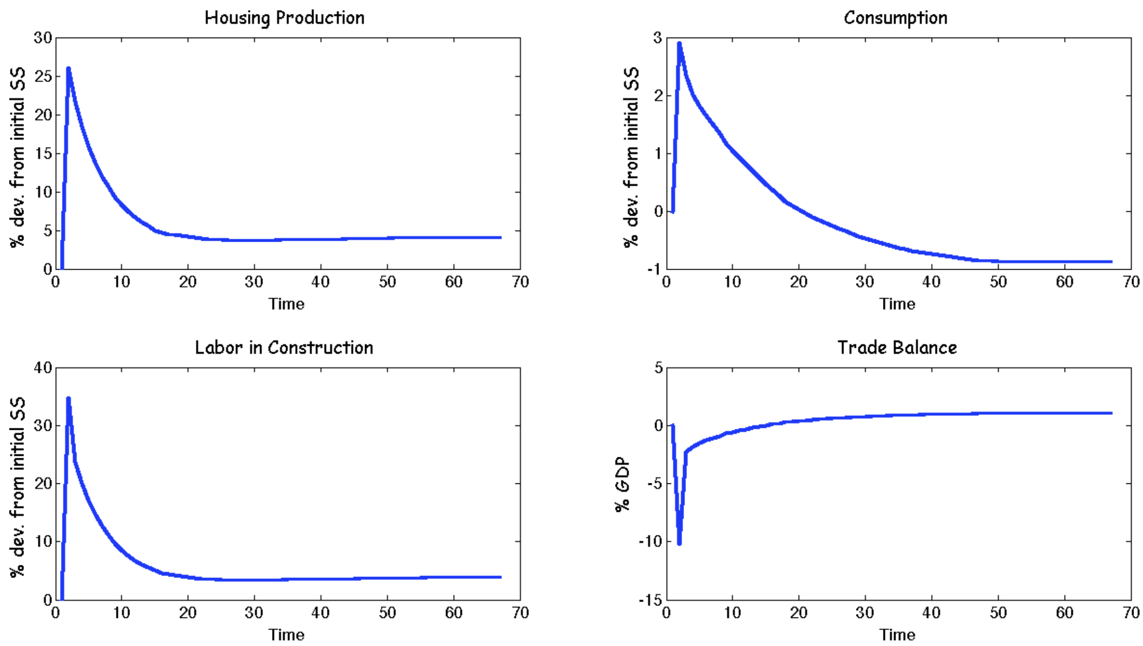


FIGURE 1.12: Housing Prices and Land Price.

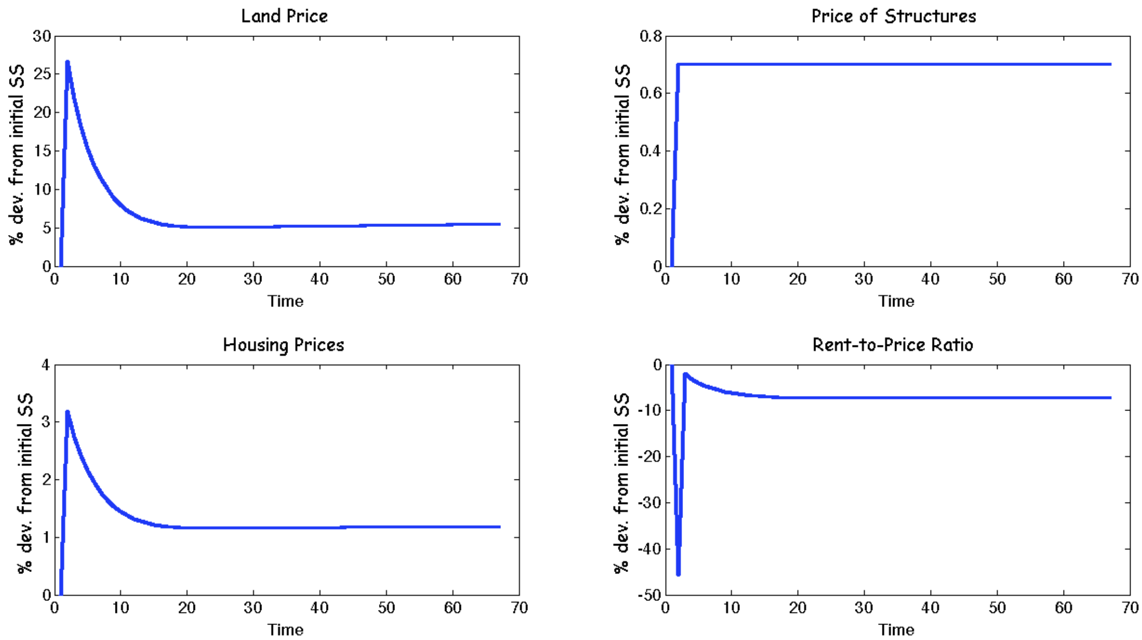


FIGURE 1.13: Housing Market.

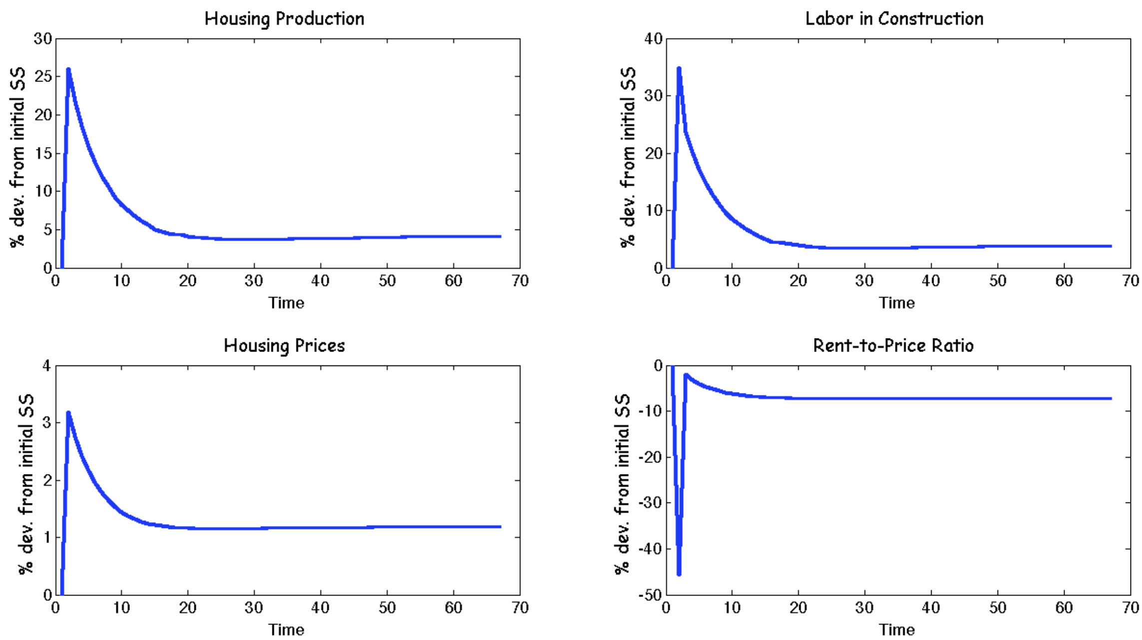
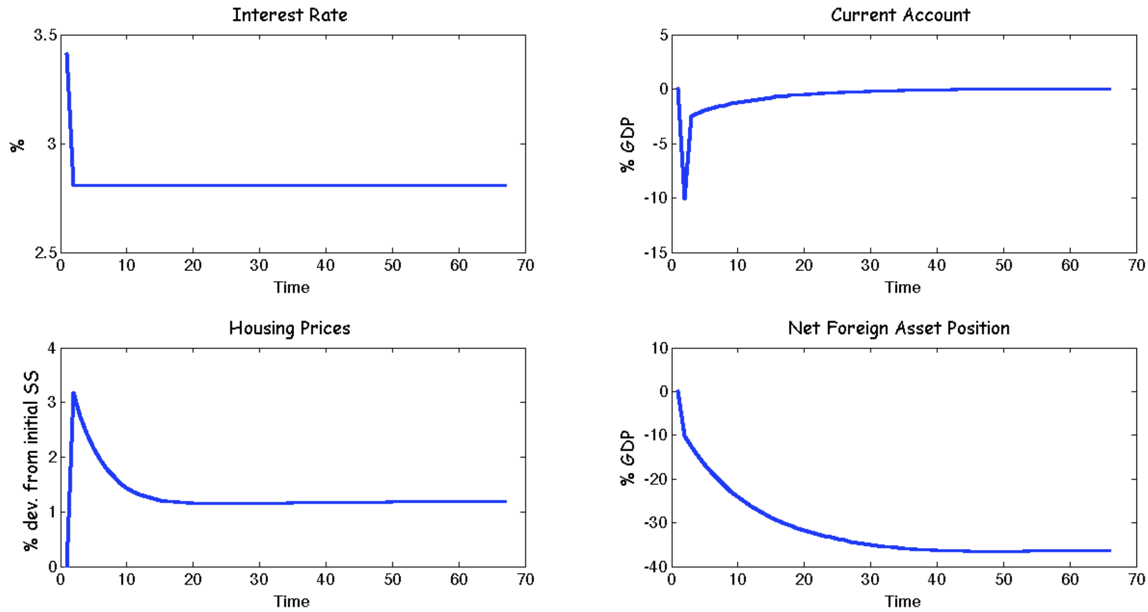


Figure 1.14: Housing Boom and International Interest Rates.



Chapter 2

Capital Goods and TFP Evolution in Spain

2.1 Introduction

The aim of this paper is to assess quantitatively the contribution of each type of capital in the evolution of measured Total Factor Productivity (TFP) and the growth experience in Spain during the period 1985-2007.

Lately, many researchers have emphasized that TFP growth is very low in Spain since the mid1990s, and that it has even become stagnant for some periods. Surprisingly this coincides with the years of highest GDP growth in the last cycle, such as the period 1995-2007 (see [19], [12]). The coexistence of high GDP growth and stagnant measured TFP cannot be accounted for by a one-sector growth model, as I show later. Moreover, it cannot account the observed investment boom also experienced in Spain during those years.

In this paper I use a version of [48] calibrated to match selected aggregates of the Spanish economy. As [48] claim, properly incorporating capital stock into the production function, i.e. differentiating between equipment and structures, implies very different measures for TFP. The objective is twofold: first, investigate quantitatively the contribution of changes in the relative price of different capital goods, equipment and structures, in the evolution of measured TFP; and second, assess the ability of this model to replicate the growth experience in Spain during the period 1985-2007. In order to asses the ability of the model in explaining the growth experience in Spain, I make use of a three-sector growth model with a wedge in structures investment, in the spirit of [17], to replicate the growth experience in Spain between 1985 and 2007. As I explain later in the text, some particularities of the Spanish economy make it difficult to incorporate structures into a model and model this particularities is beyond the scope of this paper.

A branch of the literature in growth accounting, like [8] or [65], or more recently [48], [80] or [76], relates a decrease in the relative price of investment with an increasing productivity in the investment sector. As I show in Figure 2.1,[1] this is not the case in Spain. Figure 2.1 depicts the relative price of investment in Spain, for the period 1985-2007, and compares it with other developed economies. The Spanish economy has had an increasing price of investment since 1998, with its stagnation beginning in 1995.

The increase in the relative price of total investment since 1998 is explained by changes in the prices of different investment goods, together with the composition of investment. If we split investment between equipment and structures (Figure 2.2), we find that nominal investment in structures accounts for 65% of total investment over this period. Looking to relative prices (Figure 2.3)[2] we find that the relative price of equipment has been declining over all the period, as in other developed economies, while the relative price of structures has been increasing at a large rate after 1998. Summarizing, the increase in the relative price of investment in Spain after 1998 is explained by a big share of investment in structures together with the increase in the relative price of structures.

In the search of a model able to account for the growth experience in the US, [72] show that a two-sector model, using a production function with the standard composite capital stock and taken as given the relative price of investment plotted in Figure 2.1 for the US, does improve the predictions of the model during the 90s, while the one-sector growth model seems also to fail for this country. Thus, the relative price of investment would reflect productivity changes in the investment sector, increasing investment and hour worked in the model. [20] find a similar response for the case of Finland. As I will show, and given an evolution of the relative price of investment for Spain as showed in Figure 2.1, a model like those would not improve the predictions of the one-sector growth model.

In my benchmark model economy a composite final good is produced with equipment, structures, and labor. The role that investment-specific technological change (ISTC) plays in generating growth is accounted by the decrease of the relative price of equipment. The negative impact of structures is evaluated through the big increase in the relative price of structures. I find that structures have a negative and significant impact on TFP. I also find that equipment accounts for most of the TFP growth after 1988. I compute the Hicks Neutral Productivity Change and find that it becomes stagnant after 1988.

I also find that a model with frictions that shows up as frictions in the structures market improves substantially the predictions of the model, not only for the period of the construction boom, but also for the period 1985-1998. This model accounts for the behavior of investment in equipment closely in line with standard theory. The benchmark model explains the 85%

[1] The source of this graph is Eurostat. In this graph the relative price of investment is computed as the quotient of the investment deflator over the consumption deflator from National Accounts, since INE reports to Eurostat.

[2] Relative prices are computed as the quotient of the investment deflator over the non-durables consumption deflator.

of the observed growth in real GDP per working age person in contrast with the 38% of the one-sector growth model.

In Spain, [70] asses quantitatively the contribution of each type of capital in the evolution of measured Total Factor Productivity (TFP) but with two differences: first, they do not take into account residential structures since they argue that residential capital does not belong to the concept of productive capital; and second, their analysis ends in 2002. [19] investigates the role of taxes in a one-sector growth model to evaluate its impact on long term growth. This paper focuses in the decrease in hours worked between 1975 and 1985 in Spain. The one-sector growth model with taxes accounts for a 80% of this decrease, but the evolution of taxes can not explain the behavior of real GDP, hours worked, and capital-output ratio between 1985 and 2005.

The rest of the paper is organized as follows: section 2.2 describes the three-sector model with a wedge in structures as a Base Case Model for the Spanish economy; section 2.3 describes data for Spain and the calibration process for the Base Case Model; section 2.4 discusses the results and assesses quantitatively the contribution of each type of capital on measured productivity, together with a discussion about properly incorporating capital stock in a production function for the case of Spain; section 2.5 concludes.

2.2 The Benchmark Economy

The model presented here is a three-sector model with a wedge in structures. There are two types of capital: equipment and structures. The three sectors are: consumption, equipment, and structures. However, under the assumption of equal capital shares in all sectors it can be showed it as a particular version of the one-sector growth model with different prices for non-durable consumption, equipment, and structures.[3] The motivation for the use of a wedge in structures is discussed below.

The model features a representative household that chooses paths of consumption, leisure, equipment, and structures in order to maximize utility. The household maximizes the following utility function:

$$\sum_{t=T_0}^{\infty} \beta^t \left[\gamma \log C_t + (1-\gamma)\log(\overline{h}N_t - L_t)\right] \tag{2.1}$$

subject to a sequence of budget constraints,

$$C_t + q_t^E I_t^E + q_t^S I_t^S = \omega_t L_t + r_t^E K_t^E + r_t^S (1-\tau_t^S) K_t^S + T_t \tag{2.2}$$

[3] As showed in [80].

nonnegativity constraints on C_t, $I_t^E = K_{t+1}^E - (1-\delta_E)K_t^E$, and $I_t^S = K_{t+1}^S - (1-\delta_S)K_t^S$, and constraints on the initial stock of equipment, $\overline{K}_{T_0}^E$, and structures, $\overline{K}_{T_0}^S$.

In the utility function, the parameter β, $0 < \beta < 1$, is the discount factor and the parameter γ, $0 < \gamma < 1$, is the consumption share. C_t, is consumption, I_E, is real investment in equipment, I_S, is real investment in structures, K_t^E, is the real stock of equipment, K_t^S, is the real stock of structures, L_t, is hours worked, w_t, is the wage rate, q_t^E, is the price of investment in equipment in terms of non-durable consumption, q_t^S, is the price of investment in structures in terms of non-durable consumption, r_t^E, is the rental rate of equipment, and r_t^S, is the rental rate of structures. τ_t^s is a wedge in structures investment in the spirit of [17], and T_t is per capita lump-sum transfers. The total number of hours available for work is $\overline{h}N_t$, where N_t is the working-age population and $\overline{h}$ is the number of hours available for market work. I specify $\overline{h}$ as 100 hours per week. One period of time is a year.

Firms operate in a perfectly competitive market, using a technology with constant returns to scale, which I assume to be Cobb-Douglas:

$$Y_t = Z_t (K_t^E)^{\alpha_E} (K_t^S)^{\alpha_S} L_t^{1-\alpha_E-\alpha_S}, \tag{2.3}$$

where Y_t denotes total output in non-durable consumption units, Z_t is a measure of productivity, and α_i, where $i = \{E, S\}$, $0 < \alpha_i < 1$, is the capital share in equipment (E) or structures (S). Factor prices can be derived from the condition that firms earn zero profits:

$$w_t = (1-\alpha_E-\alpha_S) Z_t (K_t^E)^{\alpha_E} (K_t^S)^{\alpha_S} L_t^{-\alpha_E-\alpha_S}, \tag{2.4}$$

$$r_t^E = \alpha_E Z_t (K_t^E)^{\alpha_E - 1} (K_t^S)^{\alpha_S} L_t^{1-\alpha_E-\alpha_S}, \tag{2.5}$$

$$r_t^S = \alpha_S Z_t (K_t^E)^{\alpha_E} (K_t^S)^{\alpha_S - 1} L_t^{1-\alpha_E-\alpha_S}. \tag{2.6}$$

I model investment in equipment and structures in a simple way similar of that proposed by [48] but allowing for different productivity growth in the structures sector. I assume that:

$$I_t^E = K_{t+1}^E - (1-\delta_E)K_t^E = \frac{X_t^E}{q_t^E}, \tag{2.7}$$

$$I_t^S = K_{t+1}^S - (1-\delta_S)K_t^S = \frac{X_t^S}{q_t^S}, \tag{2.8}$$

where q_t^i, $i = \{E, S\}$, can be understood as the cost of producing a new unit of the investment good in terms of final output. Here I_t^i, $i = \{E, S\}$, is measured in investment units for equipment (E) and structures (S), and X_t^i, $i = \{E, S\}$ is measured in non-durables consumption units. δ_E, $0 < \delta_E <$, is physical depreciation for equipment, and δ_S, $0 < \delta_S < 1$, is physical depreciation for structures. Now the feasibility constraint in non-durables consumption units of the economy will be:

$$C_t + X_t^E + X_t^S = C_t + q_t^E I_t^E + q_t^E I_t^S = Z_t (K_t^E)^{\alpha_E} (K_t^S)^{\alpha_S} L_t^{1-\alpha_E-\alpha_S} \tag{2.9}$$

2.2.1 Equilibrium and Balanced Growth Path

The model describes a representative household that chooses paths of consumption, leisure, equipment, and structures to maximize utility. The paths of productivity, relative price of equipment, relative price of structures, and population are exogenously given, and the agent has perfect foresight over their values. The model starts at $T_0 = 1985$ and let time run out to infinity.

Definition *Given sequences of productivity, Z_t, relative price of the equipment investment good, q_t^E, relative price of the structures investment good, q_t^S, wedge in structures τ_t^S, and working-age population, N_t, $t = T_0, T_{0+1}, ...$, and the initial capital stock for equipment and structures, $\overline{K}_{T_0}^i$, $i = \{E, S\}$, an **equilibrium with a wedge in structures** is sequences of wages, ω_t, interest rates, r_t^i, consumption, C_t, labor, L_t, investment in equipment and structures, I_t^i, $i = \{E, S\}$, and capital stocks for equipment and structures, K_t^i, $i = \{E, S\}$, such that:*

1. *given the wages, interest rates, and the wedge in structures, the representative household chooses consumption, labor, and capital in equipment and in structures to maximize the utility function (2.1) subject to the budget constraint (2.2), appropriate non-negativity constraints, and the constraints on $\overline{K}_{T_0}^i$, $i = \{E, S\}$;*

2. *the wages and interest rates, together with the firms' choices of labor and capital in equipment and in structures, satisfy the cost minimization and zero profit conditions, (2.4), (2.5), and (2.6); and*

3. *consumption, investment in both capital goods, labor, and capital in equipment and structures satisfy the feasibility conditions (2.7), (2.8), and (2.9).*

By taking first-order conditions of the households' problem I obtain:

$$w_t(\overline{h}N_t - L_t) = \frac{1-\gamma}{\gamma} C_t, \tag{2.10}$$

$$\frac{C_{t+1}}{C_t} = \frac{1}{q_t^E}\beta((1-\delta_E)q_{t+1}^E + r_{t+1}^E), \tag{2.11}$$

$$\frac{C_{t+1}}{C_t} = \frac{1}{q_t^S}\beta((1-\delta_S)q_{t+1}^S + (1-\tau_{t+1}^S)r_{t+1}^S). \tag{2.12}$$

This three equations, (2.10), (2.11) and (2.12), together with firm optimal conditions (2.4), (2.5), and (2.6) and the feasibility condition (2.9), compose the system of equations that can be solved to find the equilibrium of the model. Also transversality conditions are given as:

$$\lim_{t\to\infty} \beta^t \frac{\gamma}{C_t} q_{t+1}^E K_{t+1}^E = 0,$$

$$\lim_{t\to\infty} \beta^t \frac{\gamma}{C_t} q_{t+1}^S K_{t+1}^S = 0.$$

It is necessary to define a balanced-growth path for this economy.

Definition *Suppose that productivity, Z_t, and working-age population, N_t, grow at the constant rates defined in the growth accounting exercise. Then a* ***balanced-growth path*** *is a level for the wage, $\widehat{w}$, the interest rate in equipment, $\widehat{r}^E$, the interest rate in structures, $\widehat{r}^S$, consumption, $\widehat{C}$, labor, $\widehat{L}$, stock of equipment, $\widehat{K}^E$, stock of structures, $\widehat{K}^S$, and output, $\widehat{Y}$, such that $w_t = g^{t-T_0}\widehat{w}$, $C_t = (gn)^{t-T_0}\widehat{C}$, $L_t = n^{t-T_0}\widehat{L}$, $K_t^E = (gn)^{t-T_0}\widehat{K}^E$, $K_t^S = (gn)^{t-T_0}\widehat{K}^S$, $Y_t = (gn)^{t-T_0}\widehat{Y}$ satisfy the conditions for an equilibrium when the initial stock of equipment is $K_{T_0}^E = \widehat{K}^E$ and the initial stock of structures is $K_{T_0}^S = \widehat{K}^S$.*

2.3 Data and Calibration

2.3.1 The Spanish data

I use national accounts data constructed through the United Nations' System of National Accounts (SNA93), downloaded from Instituto Nacional de Estadística (INE). Data on services from different types of capital and data on hours worked per worker are taken from EU KLEMS. Working-age population is taken from the World Bank database. Data on investment deflators comes from the BBVA-Ivie database given that this database adjust prices of the high tech capital goods by quality. All the economy is involved.

In terms of data, I need measures of output, stock of equipment, and stock of structures, and hours worked. I need to take a stand on what data categories I should be including as investment. I also need to calibrate the equipment share, α_E, and the structures share, α_S.

I assume a closed economy where net exports are added to consumption. Since one of the main objectives of this paper is to deal with the evolution of capital goods, and given the big and negative value of net exports for the Spanish economy during the 2000s, adding this value to investment would distort the series for investment over GDP ratio. Hence the feasibility condition is given by:

$$C_t + X_t^E + X_t^S = Y_t,$$

where X_t^E is investment in equipment, and X_t^S is investment in structures in terms of output, i.e. in non-durable consumption units.

I define output, Y_t, as measured GDP in the national accounts. I differentiate between the stock of equipment, K_t^E, and the stock of structures, K_t^S. Investment in equipment, X_t^E, is all Fixed Gross Capital Formation but structures, and investment in structures, X_t^S, aggregates residential and non-residential structures. Consumption is then GDP minus investment.

Variables in the feasibility constraint are interpreted as physical units of an homogeneous good, with units for output and investment measured at constant prices. The procedure is to deflate both consumption and investment with the different deflators. The GDP deflator is taken from national accounts. I use BBVA-Ivie database for the equipment deflator, and for the structures deflator.

Spanish standard national accounts do not report series for the capital stock.[4] A common method to calculate series for the stock of capital is the Perpetual Inventory Method. For this procedure it is necessary to guess a capital stock at the beginning of the investment series and a value for the constant depreciation rate for each type of capital. This value is chosen to be consistent with the average ratio of depreciation to GDP observed in the data over the period used for calibration purposes.

The Perpetual Inventory Method can be applied with the investment and consumption of fixed capital in order to get the stock of capital and its depreciation rate. This approach leads to obtain the stock of equipment and structures.[5] I get a depreciation rate for equipment $\delta_E = 0.105$, and for structures $\delta_S = 0.019$.

The EU KLEMS database reports series for capital income by sectors. This database makes their calculations from the national accounts, and BBVA-Ivie reports to them investment data in the case of Spain.[6]

Following [22], I define consistent measurements of output (Y) by adding services from durables to the output (Y). In order to do this I estimate the stock of durables and services

[4]BBVA-Ivie reports series for the productive capital suitable for this analysis but they do not report the series for residential structures. By using the Perpetual Inventory Method I can estimate the stock of capital for the whole economy.

[5]See Appendix B.1 for a technical explanation.

[6]Information about the methodology of EU KLEMS database can be found in http://www.euklems.net/.

coming from these goods given data on durables consumption[7] and add the calculations to the stock of capital, GDP, and investment in the model.[8]

In order to perform my growth accounting decomposition I need to assign a value for the equipment share, α_E, and for the structures share, α_S. This can be done using the procedure outlined by [22]. Each factor share will be the flow of services of each type of capital over the GDP of the economy. I get an equipment share $\alpha_E = 0.26$, and a structures share $\alpha_S = 0.1$.

2.3.2 Calibration

To calibrate a value for β I use equations (2.5), (2.9) and (2.11) to write:

$$\beta = \frac{C_{t+1}}{C_t \frac{1}{q_t^E}((1-\delta_E)q_{t+1}^E + \alpha_E \frac{Y_{t+1}}{K_{t+1}^E})}.$$

With values for α_E, and δ_E, data on q_t^E, equipment, output, and consumption taken from data, I can compute β for each period and take the average over the period 1990-2007. In this case $\beta = 0.853$.

To calibrate a value for γ I use equations (2.4) and (2.10) to write:

$$\frac{1-\gamma}{\gamma} = (1-\alpha_E-\alpha_S)\frac{Y_t}{L_t}\frac{(\bar{h}N_t - L_t)}{C_t}.$$

With the values for α_E, and α_S, data on consumption, hours worked, population, and output it is found a value for $\gamma = 0.194$ for the same period 1990-2007.

2.3.3 Solution Method

In this model the non-durable consumption good is the numeraire. GDP is deflated by the non-durables consumption deflator since in a standard neoclassical growth model consumption is the only one that enters in utility.[9]

The best wedge is the one such that it accounts for the same investment in structures as in data. I follow the same approach that in [17] but having only one wedge. [17] solves what they call the *model with maximum investment wedge* for the US, allowing the investment wedge to replicate the data on investment and shutting down the action of the other wedges that they have. However, this model fails to predict consumption and GDP in what they

[7] I am very grateful to Ángel Estrada to provide me with these data.
[8] See Appendix B.2 for the procedure.
[9] For a discussion of this point see [55].

call the "consumption anomaly" for the case of US. As I will show this is not the case for Spain when a maximum wedge in structures is employed.

Thus, the solution method here solves the model for hours worked, equipment, and for the wedge in structures, taking structures as given by data. Equivalently, taking this wedge as given, and solving again the model for hours worked, equipment, and structures, gives the same result for investment in structures as in data. See Appendix B.3 for a description of the computational algorithm.

2.4 Results

2.4.1 Results of the Benchmark Economy

The wedge I obtain is depicted in Figure 2.4. This figure depicts the value for $(1-\tau_t^S)$ as an index with the value of 100 for 1985. The value for τ_t^S is big and negative all over the period. The intuition behind it could be a permanent subsidy to construction over this period. When $(1-\tau_t^S)$ increases the subsidy becomes bigger and when it decreases it becomes smaller. If we look to the evolution of the wedge we can observe large movements all over the period. Two remarks relative to this wedge: first, the evolution followed suggests that this wedge is very active; and second, the biggest increase of the wedge after 2000 is contemporary to the housing bubble that occurred in Spain until 2007.

Given this wedge, the results of the model are in Figures 2.5-2.8 labeled as the Base Case Model (BC). Together with the BC I plot the results for the one-sector growth model (OS) in order to see how the success in matching the same ratios change between models.[10] In the results for the BC, growth is matched for output for almost all the period but the 1995-2000 period, where the growth rate in the BC is smaller than the one in the data. The OS becomes almost stagnant after 1995. The BC is able to replicate a positive growth in hours worked over all the period, of course, still far from the evolution of this ratio observed in data. This difference between the BC and data in hours worked is what maintains the real GDP per working age person below its evolution in data. Investment-output ratio is matched with this wedge in structures pointing out the problems of the standard theory to replicate investment in residential and non residential structures for the Spanish economy.

This model not only improve the predictions for the last years of the period. As it can be seen in Figure 2.8 for consumption-output ratio, the BC match the behavior of this ratio over all the period. This is important because the OS generates an increase in the real GDP per working age person consistent with data between 1985 and 1995, but because of an increase in the consumption-output ratio and a decrease in the investment-output ratio as opposed to data. However, the BC matches the behavior for the real GDP with a better matching of these ratios.

[10]See Appendix B.4 for a description of the OS, measured TFP, and calibrated parameters.

The OS cannot account for the Spanish growth experience after 1995. In this model the only source of growth is the aggregate TFP, and its stagnation after 1995 makes the model unable to replicate the growth experience after this year. The evolution of the aggregate TFP implies a decrease in the investment and in the hours worked, thus making the OS unable to predict the growth experience in Spain between 1985 and 2007.

In the BC presented here, measured productivity[11] contributes to growth just until 1988 (as I will show below), but, after this date, the sources of growth come from the wedge in structures (i.e. from frictions modeled as frictions in the structures sector) together with Investment Specific Technological Change (ISTC). This model is able to generate growth in the real GDP per working age person between 1985 and 2007, with an improvement in the behavior of hours worked and matching the behavior of the investment-output and consumption-output ratios. Thus, being able to identify the sources of growth, or at least pointing out the ability of frictions in the structures market and ISTC, i.e. capital markets, to account for the Spanish growth experience. What I claim is that incorporating capital stock properly into the production function avoids dealing with the aggregate TFP evolution in the OS that can not rationalize the growth experience in Spain during the period studied here. Frictions showed up as frictions in the structures market and ISTC seem to have an important role in the behavior of the selected ratios of the Spanish economy. Of course, labor market frictions in Spain are important and the model presented here fails in accounting for the evolution of hours worked, even with the attained improvement with respect to the one-sector growth model.

Another point is that incorporating capital stock properly into the production function allows to model ISTC. As I will show below, a big proportion of structures in total capital stock together with the evolution of the relative price of structures after 1998 makes a composite of the capital stock into the production function, as in the OS, a bad approximation for the Spanish economy. The impact of the relative price of structures in this case will be bigger compared to the model presented here. A small amount of capital services from structures, i.e. a small value of α_S, reveals that incorporating capital stock properly into the production function matters for the Spanish economy. By doing so, the decrease in the relative price of equipment from high tech capital goods is introduced into the model and the positive contribution to productivity of this decrease can play a role. I discuss throughly this point in the next section.

Table 2.1 contains the contributions to the growth of GDP per capita from different sources as well as a summary of the improvement coming from the BC.

This exercise leads to the conclusion that frictions modeled as wedges in the investment of structures can help us to understand the behavior of the Spanish economy during the period studied here. Particularly over the years of the construction boom period but also during the period 1985-1995.

[11] In terms of [17] this measure would correspond to the productivity wedge.

2.4.2 The Investment Sector

As [48] propose, a production function properly incorporating the capital stock should distinguish between equipment and structures. The production function in (3) differentiates between equipment and structures; where K_t^E refers to equipment, K_t^S refers to structures, L_t stands for the total hours worked in the economy; and Z_t is a measure of total-factor, or neutral, productivity.

With the data for GDP, equipment, structures, and hours worked, a measure for neutral productivity can be obtained. The point in [48] relies on the fact that the relative price of equipment in the US, adjusted by quality, has been declining at a big rate and over time since the 50s. This declining pattern translates into a productivity increase in the equipment sector that affects the measure of neutral productivity. Structures in [48] are measured in the same units as GDP since they claim that the relative price of structures is close to one in the US during the period that they were working on the analysis. However, Figure 2.3 shows how this is not the case in Spain since 1998 and that is why I incorporate structures in my analysis in terms of investment in structures.

The importance of properly incorporating capital into growth accounting can be illustrated as follows. First, consider the standard one-sector growth model where output is produced according to $Y_t = A_t K_t^\alpha L_t^{1-\alpha}$, and K_t represents the standard measure of the combined stocks of equipment and structures in the same units as GDP, i.e. deflated by the GDP deflator. Figure 2.9 plots this standard measure of the Solow residual, A_t, where the productivity slowdown is apparent after 1995. Table 2.2 shows the average growth rates for this measure in different periods. Over all the period the average growth rate is 0.69, with an average of 1.07 for 1985-1995, and this value falls to more than a half for the 1995-2007 period with an average growth rate of 0.41. Second, consider a two-sector growth model where output is $\widetilde{Y}_t = A_t^1 \widetilde{K}_t^\alpha L_t^{1-\alpha}$. Here $\widetilde{K}_t$ is measured in investment units, i.e. investment deflated, and $\widetilde{Y}_t$ is in non-durable consumption units. Figure 2.9 depicts A_t^1, and Table 2.2 offers the average growth rates in different periods. Now, the measured productivity increases at a rate twice bigger than in the previous case for 1995-2007. Finally, I disaggregate the capital stock into equipment and structures, assuming the production function in equation (2.3). Figure 2.9 shows the Hicks Neutral Technological Change, Z_t, where now both stocks, equipment and structures, are measured in terms of each type of investment.

To illustrate why these differences in the measurement of productivity can vary so much from one production function to another, let us call D_t^{GDP} to the deflator of the GDP for the Spanish economy, and D_t^I to the investment deflator.

If we compute the Solow residual in the one-sector growth model we get:

$$A_t = \frac{\frac{Y_t}{D_t^{GDP}}}{(\frac{K_t}{D_t^{GDP}})^\alpha L_t^{1-\alpha}},$$

where Y_t and K_t are measured in current prices, and L_t in hours. In order to measure GDP and the capital stock in physical units both are deflated by the GDP deflator. By doing this, we assume implicitly that capital stock deflated by the GDP deflator is the number of physical units employed in production. However, a better approximation to the physical units of capital employed in production would be:

$$A_t^1 = \frac{\frac{Y_t}{D_t^{GDP}}}{(\frac{K_t}{D_t^I})^{\alpha} L_t^{1-\alpha}},$$

since capital stock is deflated by its own deflator. Now I multiply and divide the capital stock by the GDP deflator:

$$A_t^1 = \frac{\frac{Y_t}{D_t^{GDP}}}{(\frac{K_t}{D_t^{GDP}}\frac{D_t^{GDP}}{D_t^I})^{\alpha} L_t^{1-\alpha}},$$

and rearranging it I obtain:

$$A_t^1 (\frac{D_t^{GDP}}{D_t^I})^{\alpha} = \frac{\frac{Y_t}{D_t^{GDP}}}{(\frac{K_t}{D_t^{GDP}})^{\alpha} L_t^{1-\alpha}} = A_t,$$

which implies the following equation expressed in growth rates:

$$\gamma_{A_t} = \gamma_{A_t^1} + \alpha * \gamma_{\frac{D_t^{GDP}}{D_t^I}}, \tag{2.13}$$

where the ratio of both deflators is the inverse of the relative price of investment, the growth of A_t is the growth rate of the Solow residual in the one-sector growth model, and the growth of A_t^1 is the growth rate of the Solow residual in the two-sector growth model with the capital stock in units of investment. Thus, the evolution of the relative price of investment accounts for the differences in the paths followed by the two measures of productivity.

Figure 2.3[12] depicts the relative price of investment in Spain together with the relative price of equipment and structures. For comparison, I show the relative price of equipment for the US. The price of investment relative to consumption over the period 1985-2007 is depicted in Figure 2.1.[13] The evolution of this relative price in Spain contrast with those for the US and UK since the mid-90s.

[12]Relative prices are computed as the quotient between the specific investment deflator over the non-durables consumption deflator, in contrast with Figure 2.1. Figure 2.3 data have been used in all calculations along the paper.

[13]Other developed countries could be added. I just show the US and the UK data because I compare my analysis with other papers for these two countries.

The literature, for example [48] or [72], relates a decreasing trend in the relative price of investment, when prices are properly adjusted by quality,[14] with an improvement in the quality of the equipment employed in production. In other developed countries this price falls over this period, as it is expected, due to improvements in quality and the increase in quantities of the high tech capital goods, but in Spain it does not. Moreover, in Spain this relative price is increasing at a high rate since the second half of the 90s. See Figure 2.1.

There are two forces underlying this relative price evolution in Spain: one is a small investment in equipment relative to structures over all the period (Figure 2.2), and the other is a huge increase in the price of structures (Figure 2.3), both residential and nonresidential, after 1998. The small investment in equipment may seem not so strange in the 80s, according to the large amount of infrastructures built in Spain over this period, but it is very small in the 90s in comparison with other developed economies.

If we split the total investment into structures, including both residential and non-residential, and equipment, including all but structures; investment in Spain since 1985 has been characterized by a high proportion of investment in structures relative to equipment until 2007. During all the period US investment in structures has been around a 50% of total nominal investment but in the case of Spain this ratio rises until almost a 70% of total investment.

Figure 2.3 decomposes the relative price of investment into the relative price for structures and for equipment. Figure 2.3 shows the evolution for the relative price of equipment, and the behavior of this price is decreasing over time in line with the findings for the US. But when we look to the relative price of structures, Figure 2.3 provides a clue about the differences in the behavior of the relative price of investment in Spain. It is the big share of structures in total investment together with the evolution in this relative price for structures what makes the relative price of investment to evolve like we see in Figure 2.1.

Thus, equation (2.13) implies that big changes in the relative price of investment affect the evolution of the aggregate TFP in the one-sector growth model. Moreover, as it is the case for the Spanish economy, an increase in the relative price of investment leads to a decrease of the aggregate TFP when measured as in the traditional growth accounting. Since the year 1995, the Solow residual in the one-sector growth model grew at an average growth rate of 0.41, and the relative price of investment average growth rate was 0.47. So, given equation (2.13), the Solow residual would have grown at an average growth rate 42%. This amount is bigger than it actually does in the one-sector growth model by properly incorporating capital stock into the production function. This can be seen also by comparing A_t and A_t^1 in Figure 2.9.

Many papers, as [19] or [12], find the same pattern for aggregate TFP, A_t, in Spain. When this measure of productivity is used as the aggregate TFP in the one-sector growth model, the implied behavior of GDP of this model completely misleads data for the Spanish economy.

[14] As it is the case in Spain for the data from Ivie-BBVA and used in Figure 2.3.

The slowdown tendency after 1995 imply a disincentive for investing and working in this economy, causing an stagnation of the GDP as opposed to data. See Figures 2.5-2.8.

Given equation (2.13), when the relative price of total investment decreases over time its impact on aggregate TFP growth is positive, as it is the case in the US. [72] develop a two-sector growth model for the US with a production function with one composite capital stock measured in investment units and output in consumption units. They use as the relative price of investment for the US the one plotted in Figure 2.1 and find that this model improves the predictions for the US economy when compared with the one-sector version. The decreasing price of investment will make investment in capital more productive, increasing investment and hours worked. In the case of Spain, a model like the one presented in [72] would not reflect this productivity improvement after 1998. Instead of the increase in productivity after 1998, A_t^1 in Figure 2.9, the huge increase in the price of investment after 1998 would disincentive investment and hours worked. Thus, the benefit from increasing productivity in equipment, as showed in Figure 2.3 with the decrease in the relative price of equipment as in the US case, would not be reflected in the relative price of investment, making a model for Spain like the one presented in [72] useless to improve its predictions about the Spanish growth experience for 1985-2007.

Three reasons make a production function like (2.3) a more accurate assumption for the Spanish economy: first, the big proportion of structures in the total capital stock; second, the small value of services from structures, i.e. a small α_S, relative to the proportion of structures in the composite capital stock; and finally, the pattern followed by q_t^E and q_t^S. The large share of structures in total investment will imply that the relative price of aggregate investment is strongly determined by the evolution of this relative price of structures. When capital is aggregated as in the one-sector growth model, this relative price has a big impact on aggregate TFP since capital services from all capital are strongly determined by equipment with an $\alpha = 0.36$. However, when this capital services are calculated for each kind of capital, a bigger amount of services come from equipment. This particular case occurs when we compare the calibrated values of α_E and α_S.

Once that the capital is properly incorporated into the production function, the measured productivity becomes Z_t, which is the standard Hicks Neutral Technological Change. The Hicks Neutral Technological Change had a positive growth until 1988, but it became stagnant until 2007.

2.4.3 The Effect of Capital Goods on measured TFP

Following [48], since a decrease in the relative price of equipment is related with increasing productivity in this kind of capital goods, an increase in the relative price of structures would be associated with a decreasing relative productivity in the sector producing structures. So, I allow the model to have two different capital goods into the production function, equipment and structures. Since none of these relative prices are constant in Spain, different productivity changes are allowed in those sectors producing equipment and structures, relative to the non-durables consumption sector. This section focuses on how this model accounts for the negative impact of structures and the positive impact of equipment on aggregate TFP.

I assume one production function for each of the three sectors in the economy: consumption, equipment and structures, allowing for different TFP growth rate in each sector:

$$C_t = Z_t (K_t^{CE})^{\alpha_E} (K_t^{CS})^{\alpha_S} (L_t^C)^{1-\alpha_E-\alpha_S},$$

$$I_t^E = A_t^E (K_t^{EE})^{\beta_E} (K_t^{ES})^{\beta_S} (L_t^E)^{1-\beta_E-\beta_S},$$

$$I_t^S = A_t^S (K_t^{SE})^{\gamma_E} (K_t^{SS})^{\gamma_S} (L_t^S)^{1-\gamma_E-\gamma_S},$$

where all sectors produce using equipment, structures, and labor. The consumption sector is composed by non durable consumption. Consumption of durables is included in the equipment sector. For this reason the output in the economy is measured in non-durables consumption units:

$$Y_t = C_t + X_t^E + X_t^S$$

where

$$X_t^E = q_t^E I_t^E; \text{ and } X_t^S = q_t^S I_t^S$$

q_t^E, q_t^S are the relative prices of equipment and structures respectively. Capital is accumulated according to:

$$K_{t+1}^E = I_t^E + (1-\delta_E) K_t^E; \text{ and } K_{t+1}^S = I_t^S + (1-\delta_S) K_t^S$$

Given the scarcity of data in Spain to find the capital services in each sector, I assume equal factor shares,[15] $\alpha_E = \beta_E = \gamma_E$ and $\alpha_S = \beta_S = \gamma_S$.

By assuming equal factor shares, it is straightforward to show that this model is equivalent to a model with one production function:

[15] See Appendix B.5 for an intuition of the case with different factor shares.

$$Y_t = Z_t (K_t^E)^{\alpha_E} (K_t^S)^{\alpha_S} (L_t)^{1-\alpha_E-\alpha_S}$$

where K_t^i, $i = E, S$ is all capital of this type in the economy, and L_t is total hours worked in the economy.

Aggregate TFP growth rate (μ) can be computed as:

$$\mu = \gamma_Z + \alpha_E \gamma_{1/q^E} + \alpha_S \gamma_{1/q^S}$$

where γ refers to the growth rate of each variable. The contribution of structures and equipment to the aggregate TFP growth rate is given by:

$$\frac{\alpha_i \gamma_{1/q^i}}{\mu} \quad for \quad i = S, E$$

Given the series for Z_t, the calibrated values for α_E and α_S, and the relative prices q^E and q^S, I can compute the contribution of each kind of capital on aggregate TFP. The results are in Table 2.3, as average contributions over each period. For all the period 1985-2007, there is a small but negative contribution from structures to aggregate TFP. However, if we look to the years of the high increase in prices of structures 2001-2007 this contribution can explain a 27.75% of the actual decrease of the Spanish aggregate TFP. This value is an upper bound to the negative impact of structures on aggregate TFP since there is evidence of the existence of a bubble in the price of structures over this period. The other result is the important contribution on aggregate TFP coming from equipment. In all the period, and given the increase in the relative price of equipment in the middle 80s and in the beginning of the 90s, more than a half of the TFP growth was coming from equipment. Conversely, after 1995 the contribution of equipment to TFP growth was bigger than a 100% of the actual growth of the aggregate TFP.

2.4.3.1 Growth Accounting

With this production function, I develop a growth accounting based on that of [50]. Suppose that TFP and the working-age population grow at constant rates,

$$Z_{t+1} = g^{1-\alpha_E-\alpha_S} Z_t,$$

$$N_{t+1} = n N_t,$$

where $(g^{1-\alpha_E-\alpha_S}-1)$ is the growth rate of TFP and $(n-1)$ is the growth rate of population. Thus, there is a balanced-growth path in which output per working-age person, Y_t/N_t, grows at the rate $(g-1)$ and the equipment-output ratio, K_t^E/Y_t, the structures-output ratio, K_t^S/Y_t, and hours worked per working age person, L_t/N_t, are constant. That such a path is feasible follows from plugging $Z_{t+1} = g^{1-\alpha_E-\alpha_S}Z_t$, $K_{t+1}^E/N_{t+1} = gK_t^E/N_t$, and $K_{t+1}^S/N_{t+1} = gK_t^S/N_t$ into the production function,

$$\frac{Y_{t+1}}{N_{t+1}} = Z_{t+1}\left(\frac{K_{t+1}^E}{N_{t+1}}\right)^{\alpha_E}\left(\frac{K_{t+1}^S}{N_{t+1}}\right)^{\alpha_S}\left(\frac{L_{t+1}}{N_{t+1}}\right)^{1-\alpha_E-\alpha_S} =$$

$$= gZ_t\left(\frac{K_t^E}{N_t}\right)^{\alpha_E}\left(\frac{K_t^S}{N_t}\right)^{\alpha_S}\left(\frac{L_t}{N_t}\right)^{1-\alpha_E-\alpha_S} = g\frac{Y_t}{N_t}.$$

Then, it is possible to rewrite the production function as

$$\frac{Y_t}{N_t} = (Z_t)^{\frac{1}{1-\alpha_E-\alpha_S}}\left(\frac{K_t^E}{Y_t}\right)^{\frac{\alpha_E}{1-\alpha_E-\alpha_S}}\left(\frac{K_t^S}{Y_t}\right)^{\frac{\alpha_S}{1-\alpha_E-\alpha_S}}\left(\frac{L_t}{N_t}\right).$$

In a balanced-growth path, $\left(\frac{K_t^E}{Y_t}\right)^{\frac{\alpha_E}{1-\alpha_E-\alpha_S}}$, $\left(\frac{K_t^S}{Y_t}\right)^{\frac{\alpha_S}{1-\alpha_E-\alpha_S}}$, and $\left(\frac{L_t}{N_t}\right)$ are constant, and growth in $\frac{Y_t}{N_t}$ is driven by growth in $(Z_t)^{\frac{1}{1-\alpha_E-\alpha_S}}$.

Figure 2.10 depicts this growth accounting when capital stock is incorporated separately, and in terms of investment units. Some features arise from this exercise: first, equipment is an important source of growth since 1988; second, aggregate TFP, or hicks neutral productivity change, has a positive impact until 1988. After this year it has a negative impact on growth until 1993, it recovers in two years but becomes stagnant between 1995 and 2007. Third, labor has a very important contribution to growth throughout all the period in line with the findings of the one-sector model. Finally, structures fluctuates around a balanced growth path with a slightly negative impact over all the period, in contrast with the huge amount of structures built in Spain in the years of the construction boom before 2007.

2.4.4 The Structures Market in Spain

From the previous exercise, it seems interesting to see how structures have almost no contribution to growth in comparison with equipment when a huge amount of structures has been built in Spain between 1995 and 2007. Figure 2.11 shows data for investment as a percentage of the GDP in Spain from 1985 to 2007. Total investment is a 20% of the GDP in 1985, and more than the 30% in 2007. Investment in structures strongly determines the evolution of total investment. From 1985 to 1995, non-residential investment drives the investment in structures, but, after 1995, residential investment pushes up total investment, whit a smaller contribution of non-residential structures, from around a 8% over GDP to a 10% in 2007. Figure 2.12 depicts public investment to show the large increase of public non-residential structures until the beginning of the 1990s, when this investment almost doubles its weight over GDP from a 2% in 1985 to around a 3.5% in 1990.

The construction of residential and non-residential structures in Spain, specially between 1995 and 2007, has many sources of growth pointed out in the literature:

- *Credit bubble*: A well documented credit bubble from an accommodative monetary policy and the easing in financial conditions all over the world, among other factors, decreased international interest rates (real ex-post interest rates dropped by 10 points between 1990 and 2005) and allowed for large financing to peripheral countries of the Euro Zone. See [38], [41], [68], and [67]. Another reason for a decreasing pattern in international interest rates is the *savings glut hypothesis* by [11]. Also the creation of the Euro per se implied a convergence pattern in interest rate among the Euro countries that benefited peripheral countries like Spain. Mortgage rates followed the decline in yields on government securities. In many countries, on the other hand, spreads between mortgage rates and benchmark government bond rates also narrowed significantly, as a result of increased competition, changes in risk assessment and sometimes cross-subsidisation of products by banks. See [4].

- *Household real disposable income*: During the period between 1995 and 2007, an unprecedented declining in the unemployment rate[16] and a steady income growth contributed to increase the housing demand. [74] decompose house prices changes since 1996 to 2006 for 14 OECD countries. They find that real income growth contributed about 38 percentage points to real house prices in Spain.

- *Demographic factors*: Another demand factor putting pressure in the real estate boom came from demographic characteristics. Two sources had an impact in Spain: first, the percentage of population between 15 and 64 increased dramatically in Spain between the mid 1970s and 2007; and second, an immigration boom increased the working age population in Spain. Foreign-born share in the working-age population went from 2 to 16 percent between 1998 and 2008. Immigration led to an average between 1.5 percent and 2 percent annual increase in the working-age population. See [38] and [45]. According to the National Immigrant Survey, almost 40 percent of all immigrants were homeowners in 2007. In addition, the increased demand for housing rentals is likely to have stimulated the demand for purchases of new housing units as an investment. [45] find that this flow of immigrants can explain a quarter of the increase in housing prices and a half of the construction activity between 2000 and 2010.

- *Demand by non-residents*: Housing demand by non-resident was increasing in Spain. Among the factors influencing these acquisitions are the increased number of retired

[16] A 8% reached in 2007 was the smaller unemployment rate in Spain since 1985.

people in Europe, the creation of the euro, or the reduction in transport costs especially as a result of the expansion of low cost airlines, as pointed out by [4]. In Spain, housing investment by non-residents has grown at an annual rate of more than 20% from the end of the 1990s to 2003. In 2003 it represented around 10% of total residential investment and about 0.9% of GDP. See [27].

- *Mortgage innovation*: Product innovations aimed to make easier to afford a house in a context of rising housing prices are well documented. Extension of loan terms or increased loan-to-value ratios, among others, seem to have had a big impact on housing demand in Spain. Deregulation and mortgage innovations reduced borrowing constraint on households. See for example [4].

- *Preference tax treatment for housing*: As pointed out in [4], three main advantages are given to homeowners in most of the OECD countries and, particularly, in Spain. Imputed rents are not taxed; mortgage interests related to the main residence, and principal repayments up to a certain level, are deductible from personal income tax; and owner-occupied dwellings are exempted from taxes on capital gains, under the condition that the proceeds are reinvested.

- *The existence of "Cajas"*: In Spain, there was a complex relation between politics and finance that characterize the growth of *cajas*, Spanish credit institutions dominated by local political elites. See for example [38] or [75]. [38] points out two key changes in the regulation of cajas. The first one was introduced in 1985 when the control of these institutions was transferred to the regions, allowing for their capture by local politicians. The second was introduced in 1988 (with some exceptions further removed in 1992) when cajas were allowed to expand territorially. The cajas channeled lending in an indiscriminate manner to real estate developers with a consequent boom in construction. The number of housing units built (completed) grew every year from around 150000 in 1995 to 600000 in 2006. The number of houses started in 2005 in Spain was 750000, while in the UK, a country with a one-third bigger population, 250000 units were started in the same year.[17] Some cajas also financed large infrastructure projects of regional governments, as it is the case for Caja Madrid or Bancaja.[18] As a consequence of the relation between politics and finance, local governments were infected by the pervasive corruption engendered by the real estate boom.

The literature points out all these factors as candidates to having prompted a housing bubble[19] and the indiscriminate construction of the so called *white elephants*[20] that occurred in Spain between 1995 and 2007. As [10] or [9] claim, the construction of infrastructures in Spain has been not driven by the economic activity.

[17] See "Building blocks", The Economist, Sep 14, 2006.
[18] See "Tierra de saqueo", El País, Jan 15, 2012.
[19] See for example [37].
[20] See "Elefantes Blancos", El País, May 18, 2010; "Carné de ruta por el despilfarro, Nada es Gartis, Nov 11, Nov 26, Nov 27, Nov 28, 2010; "Sobre jarrones chinos, errores estadísticos e infraestrcuturas", Nada es Gartis, Mar 15, 2012.

All these factors together are difficult to incorporate in a model. That is why I proceed as [17] by making use of a wedge in structures. The idea is to make the model able to match structures as in the data by introducing a wedge. So, the objective is to answer the question if a model with frictions in the structures market can replicate the growth experience in Spain, and how much a model of this type improves the predictions for the Spanish economy.

Because the literature has explained the behavior of equipment in other developed economies given the evolution of the relative price of equipment, and as I showed in Figure 2.3 this price behaves in the same way in Spain than in other developed countries, I found no reason for a wedge in equipment. Moreover, I want to see if the standard theory can explain the evolution of this kind of capital goods.

2.5 Final Comments

In this paper I split capital into equipment and structures and show how a model with frictions showed up as frictions in the structures market, i.e. introducing a wedge in structures in the spirit of [17], could explain the evolution of the investment-output ratio. Also how it improves substantially the behavior of the prediction for hours worked, of course, still far from being explained given labor market frictions widely studied in the literature that are not the focus of this paper. Equipment in Spain behave as the standard theory predicts. No frictions in the equipment market is needed to closely replicate the behavior of this kind of investment in Spain.

Moreover, besides the clear pattern followed by investment in structures after 1995 in the Spanish economy, the model with a wedge in structures seems to improve also the behavior of the economy from 1985-1995. This is thanks to a better matching of the consumption-output and investment-output ratios compared with the predictions of the one-sector growth model.

I have also computed a growth accounting exercise for Spain, and I have quantified the contribution to aggregate TFP from different capital goods. In one side, the positive impact from equipment given that quality adjusted relative prices has been decreasing over the period under study 1985-2007, and in the other side, the negative impact from structures given the relative price increase after 1998 and the poor performance of Spanish TFP after 1995.

Given the Hicks Neutral Technological Change obtained it can be said that investment in equipment has contributed strongly and positively to TFP growth after 1988, year in which Hicks Neutral Technological Change becomes stagnant and negative for some periods, and until 2007. After 1988 the only source of TFP growth in aggregate TFP came from equipment.

The negative impact on TFP growth from investment in structures has been measured, and the period more affected by structures is 2001-2007, with a negative impact of 27.75% of the decrease in TFP growth rate.

Of course, further research is needed because despite of the ability of the model to improve substantially the predictions for the main ratios in the Spanish economy, frictions showed up as frictions in the structures market should be investigated. What this paper points out is the ability of such frictions to improve the predictions of any model.

Table 2.1: Results.

	Data	One Sector	Base Case
Growth 1985-2007			
change in Y/N	2.33	0.88	1.96
due to A_t	0.87	0.87	
due to K/Y	-0.1	0.27	
due to Z_t	0.33		0.20
due to Ke/Y	0.76		1.05
due to Ks/Y	-0.06		0.12
due to L/N	1.29	-0.25	0.59
Growth 1985-1995			
change in Y/N	1.97	1.48	2.17
due to A_t	1.25	1.25	
due to K/Y	-0.16	0.37	
due to Z_t	0.82		0.84
due to Ke/Y	0.65		1.05
due to Ks/Y	-0.04		-0.10
due to L/N	0.54	-0.13	0.38
Growth 1995-2001			
change in Y/N	2.80	0.52	1.09
due to A_t	0.61	0.61	
due to K/Y	-0.5	0.37	
due to Z_t	-0.52		-0.67
due to Ke/Y	0.76		1.08
due to Ks/Y	-0.15		0.25
due to L/N	2.70	-0.46	0.43
Growth 2001-2007			
change in Y/N	1.75	0.07	1.93
due to A_t	0.29	0.29	
due to K/Y	0.41	-0.06	
due to Z_t	0.31		-0.02
due to Ke/Y	0.72		0.71
due to Ks/Y	0.01		0.31
due to L/N	0.71	-0.15	0.92

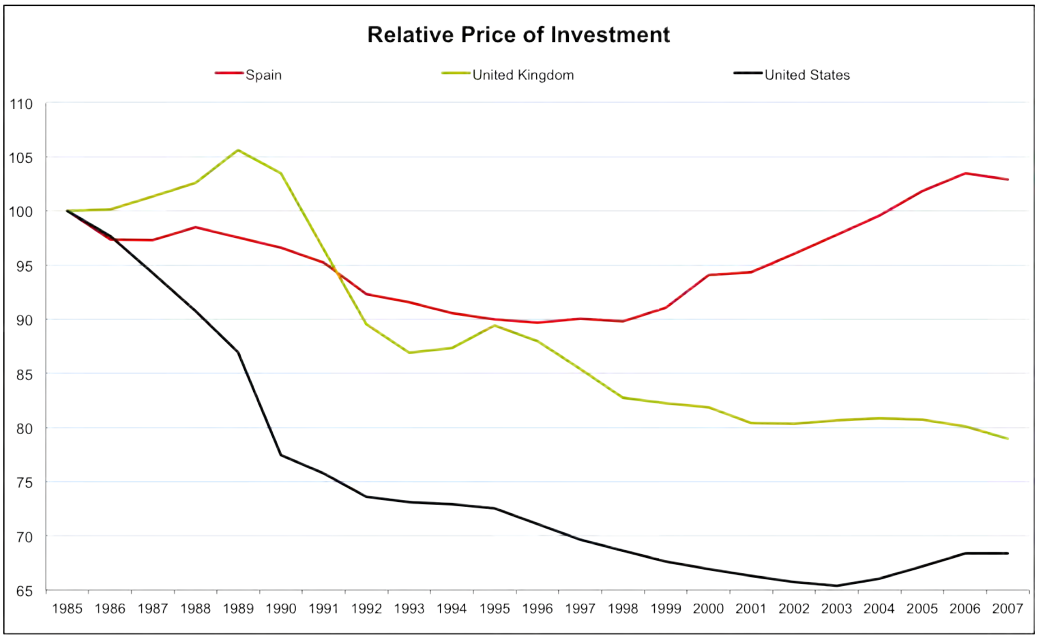
Table 2.2: Average Productivity Growth Rates.

	A_t	A_t^1	Z_t
1985-2007	0.69	0.77	0.38
1985-1995	1.07	1.07	0.88
1995-2007	0.41	0.79	0.11

Table 2.3: Contribution to Aggregate TFP.

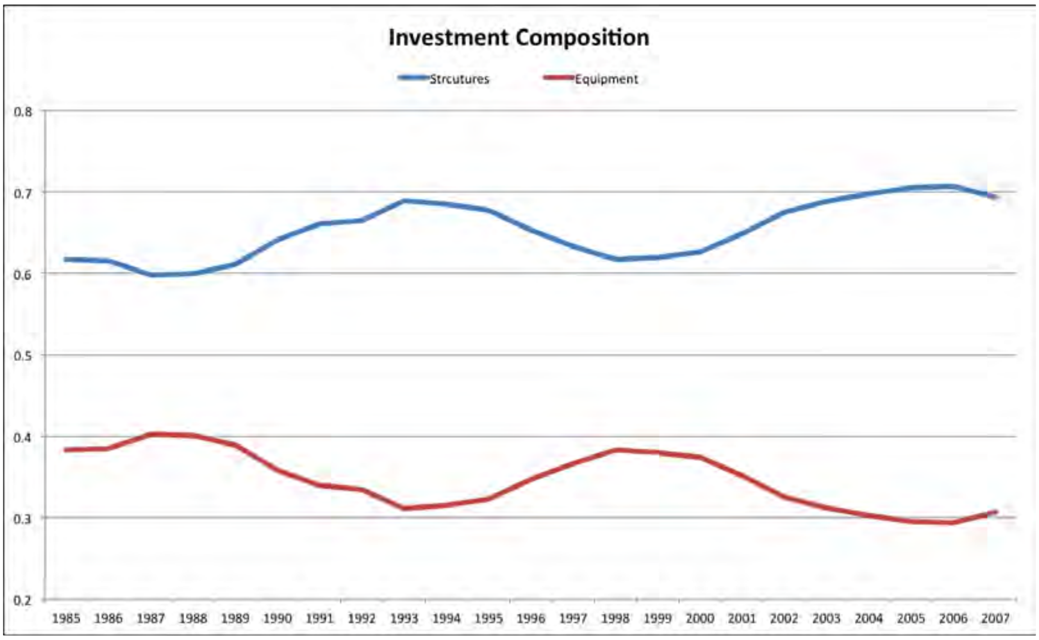
	Equipment	Structures
1985-2007	86.29%	-5.64%
1985-1995	55.87%	1.39%
1995-2001	144%	-13.11%
2001-2007	135.02%	-27.75%

Figure 2.1: Relative Price of Investment.



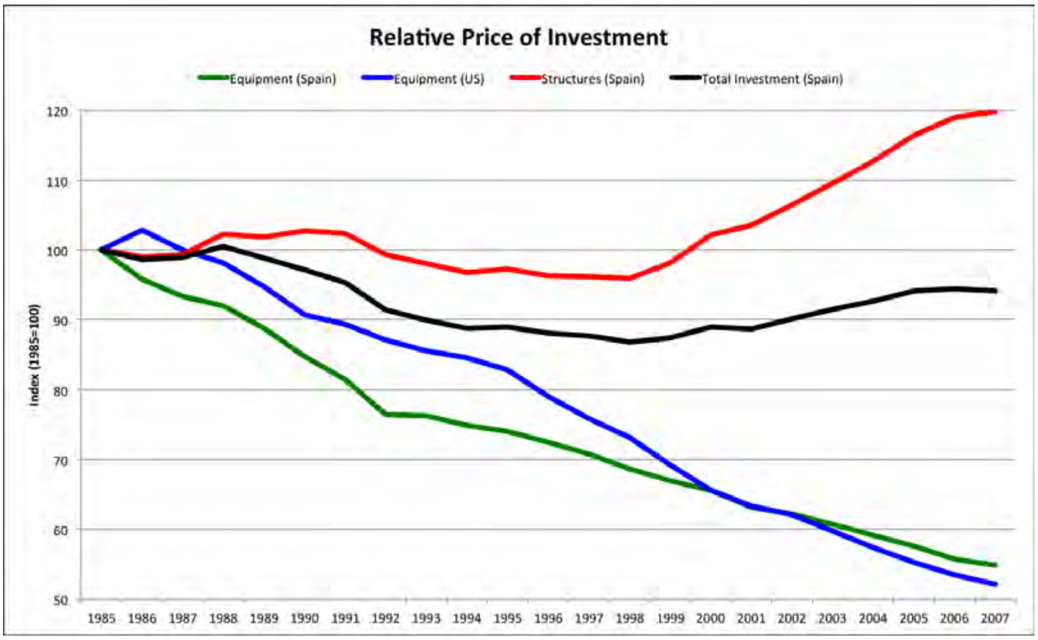
Source: Eurostat.

Figure 2.2: Nominal Investment.



Source: BBVA-Ivie.

FIGURE 2.3: Price of Investment in Spain.



Source: BBVA-Ivie, Ángel Estrada.

FIGURE 2.4: Structures Wedge.

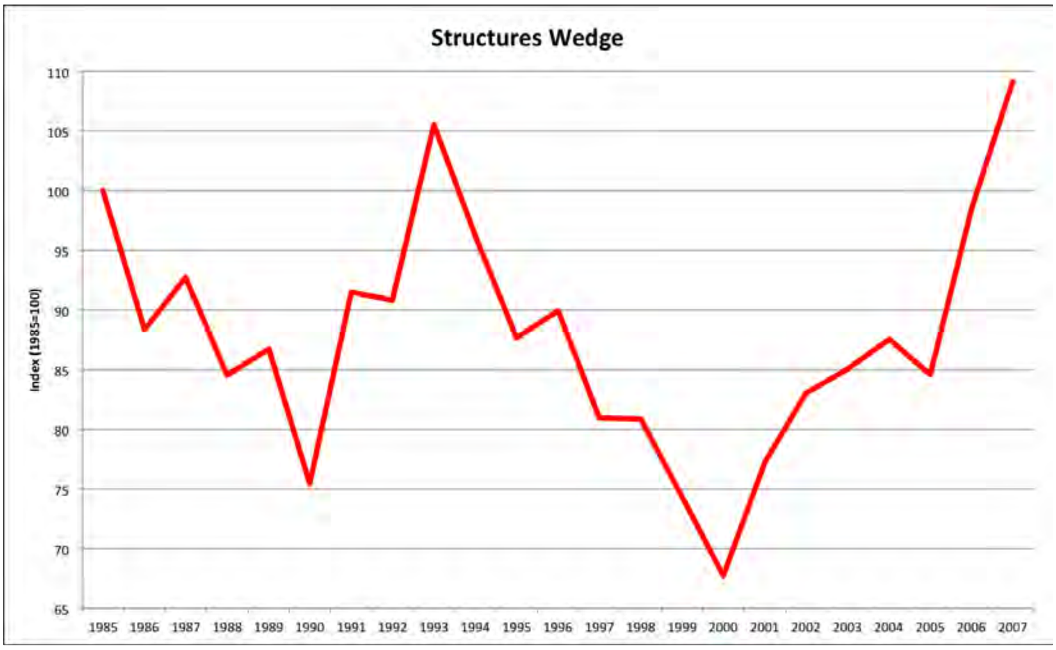


Figure 2.5: Real GDP.

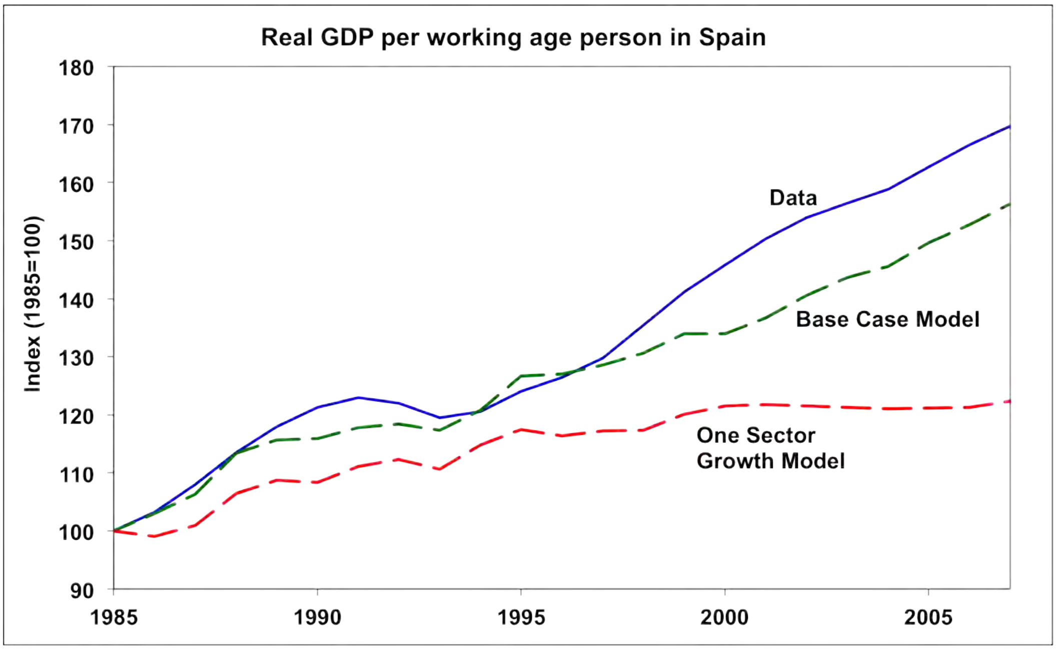


Figure 2.6: Hours worked.

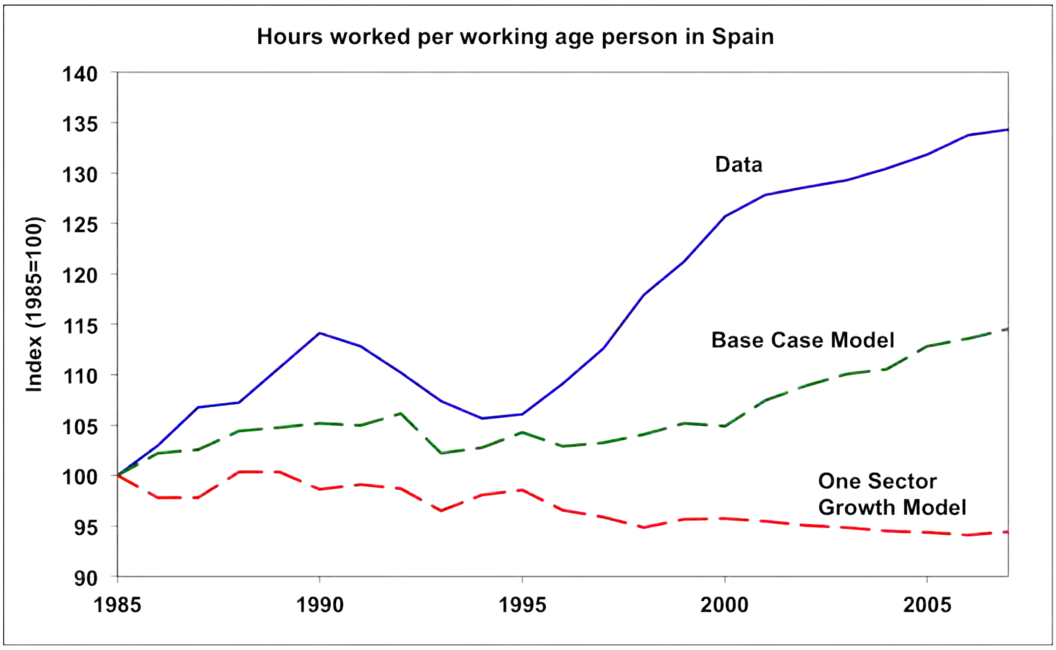


Figure 2.7: Investment/Output ratio.

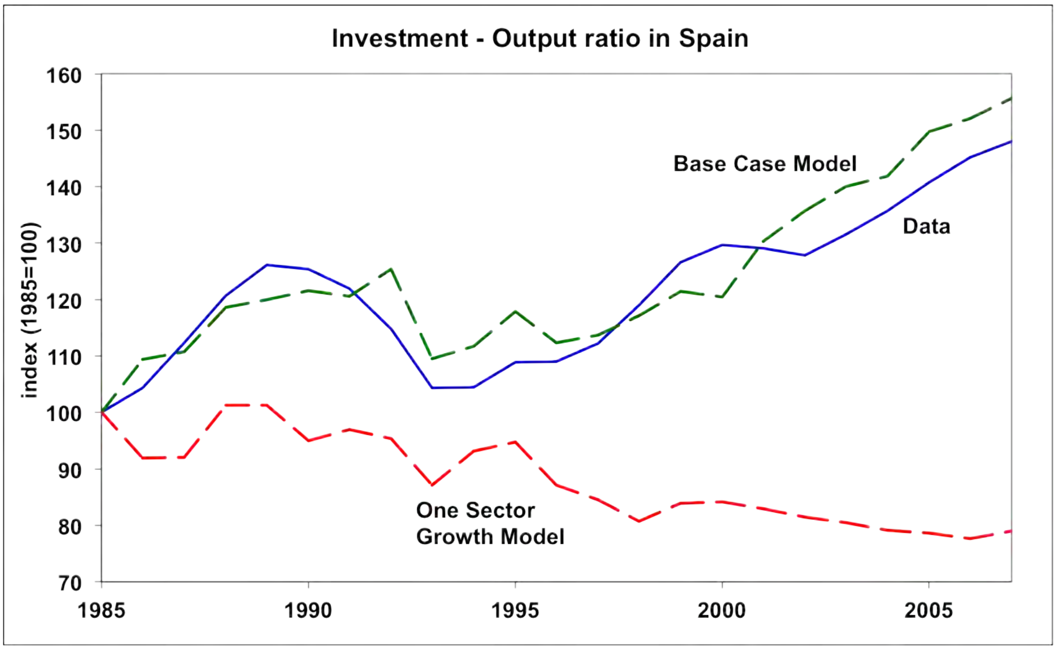


Figure 2.8: Consumption/Output ratio.

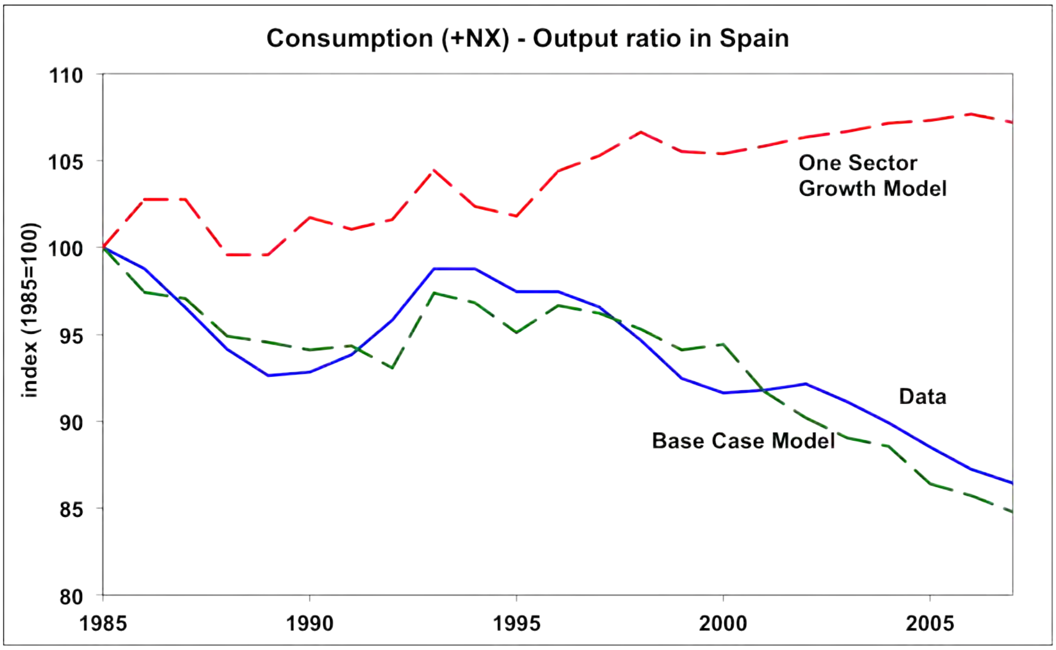


FIGURE 2.9: Hicks Neutral Technological Change.

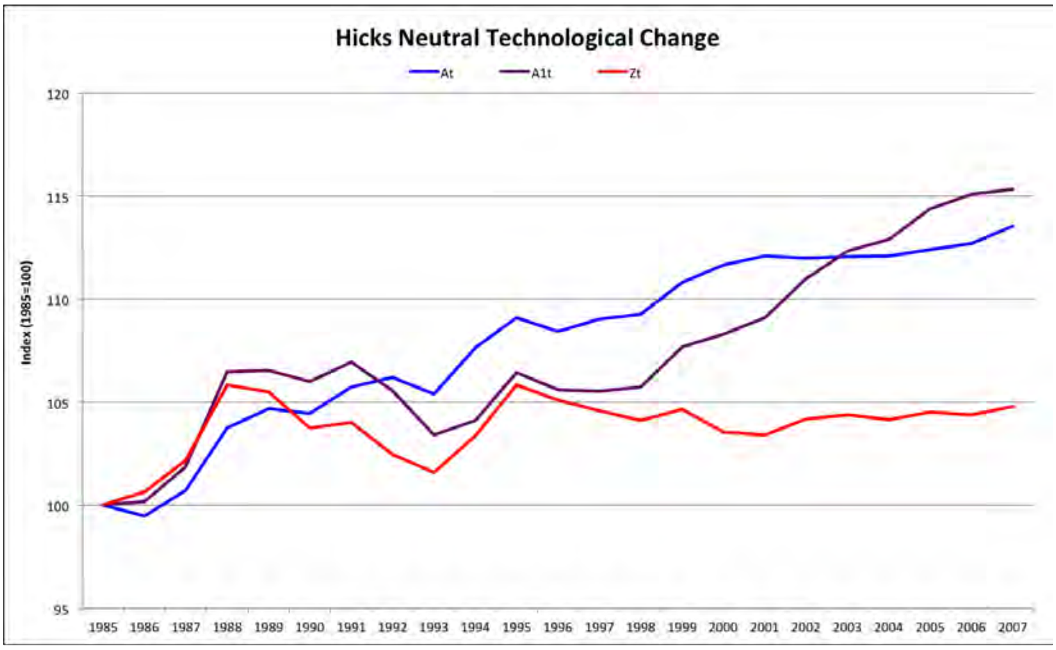


FIGURE 2.10: Growth Accounting.

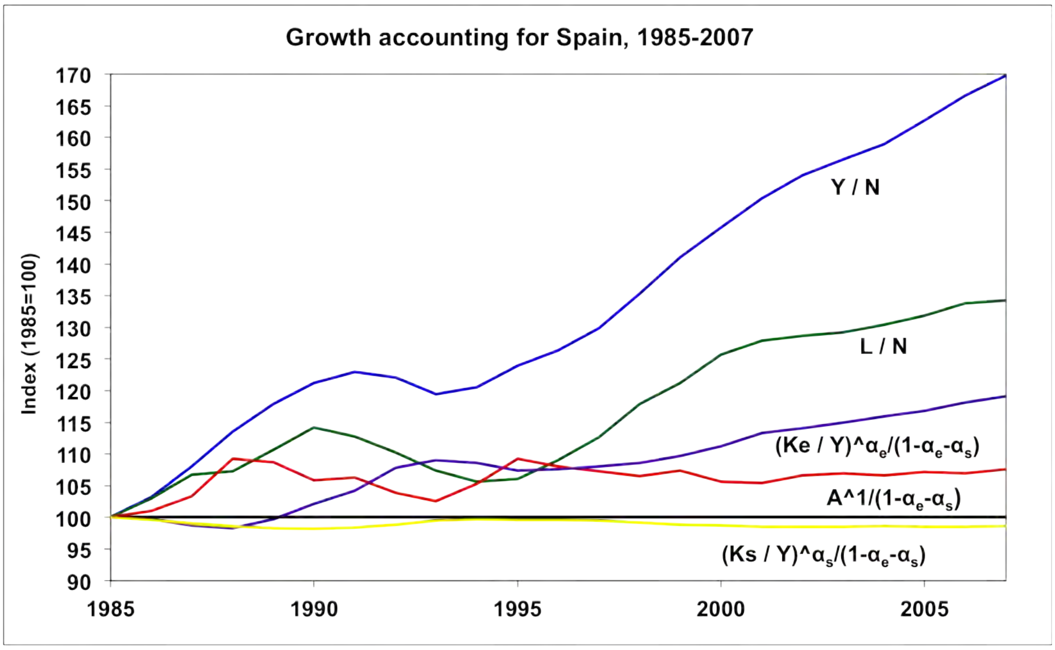
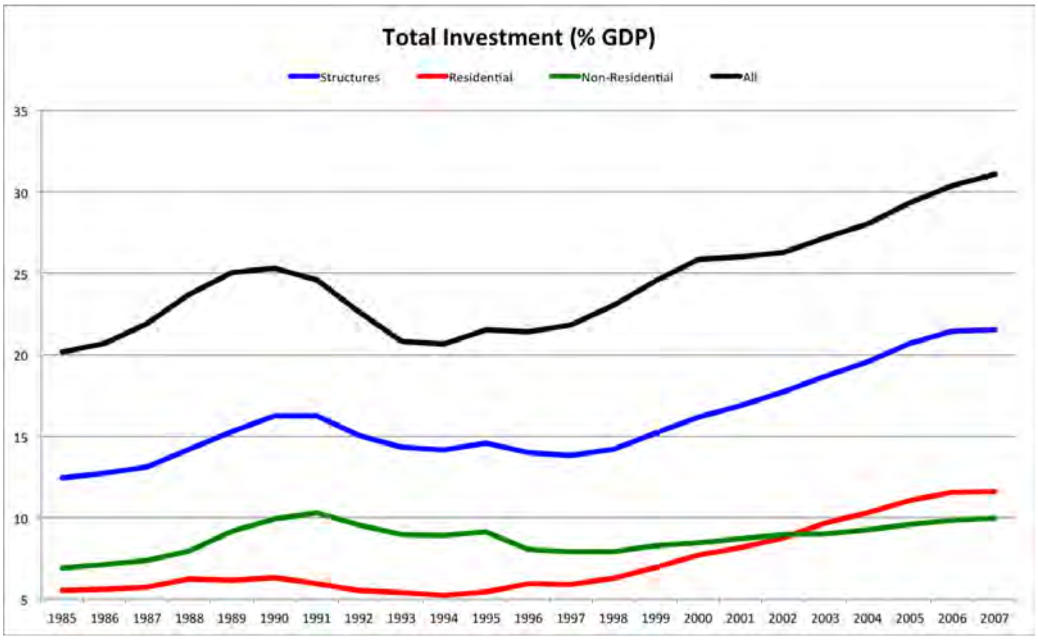
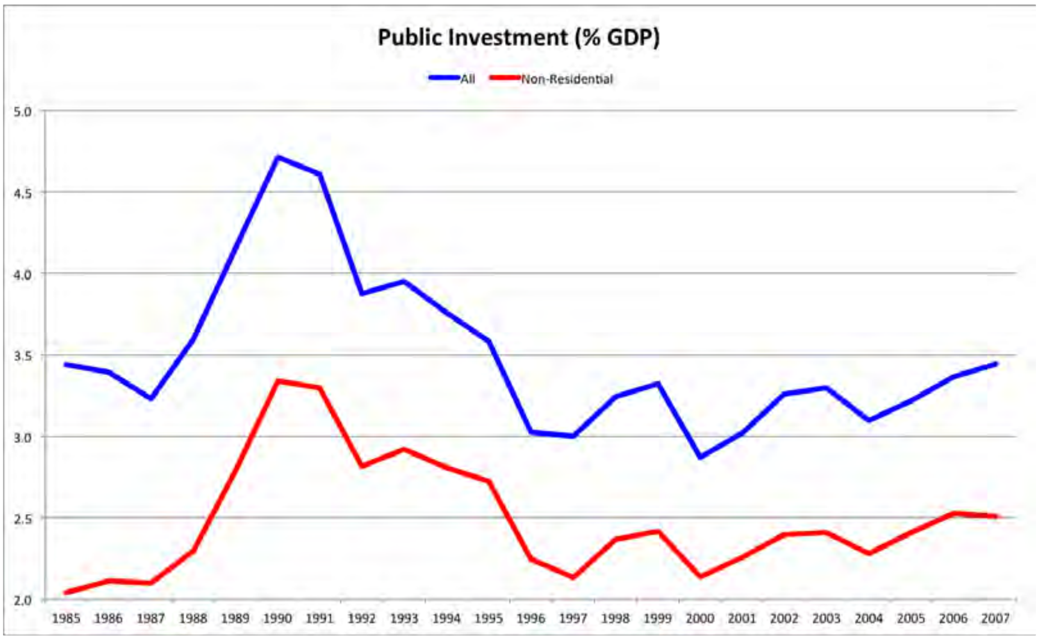


Figure 2.11: Total Investment.



Source: BBVA-Ivie.

Figure 2.12: Public Investment.



Source: BBVA-Ivie.

Appendix A

Appendix to Chapter 1

Appendix A.1: Computational Procedures

The first thing to do is to calculate the initial steady state and the final one. The computational procedure for the transition is based on [51].

Households Own Land

The budget constraint is reduced with some assumptions. The first one is relative to the amount of land households hold in the economy. I assume that households have a proportion of the total land in the economy relative to their housing stock, and they receive this amount of land exogenously each period. To have an intuition of this assumption think on the steady state. Each period households have to cover the amount of housing capital depreciated and construct it on the new plot of land that they receive that period. So, rents from land are received by households in a proportional amount to their housing stock. This assumption makes possible to have land in the economy owned by individuals.

In this sense I make use of the Cobb-Douglas production function for houses to derive the relationship between land and the housing stock, and from the marginal product of land I get:

$$p_t^l l(h_t, h_{t+1}) = \phi p_t^h (h_{t+1} - (1-\delta_h)h_t)$$

Using this expression the budget constraint becomes:

$$c_t + r_t^f p_t^h f_t + a_{t+1} + p_t^h (1-\phi) h_{t+1} \leq$$

$$\leq z^i(1-\tau_y)w_t + b_t^{j>j^*} + (1+(1-\tau_y)r_t^a)a_t + (1-\delta_h)p_t^h(1-\phi)h_t$$

Now, I add the term $p_{t-1}^h(1-\phi)h_t$ to both sides of the budget constraint. Rearranging I get:

$$c_t + r_t^f p_t^h f_t + a_{t+1} + p_t^h(1-\phi)h_{t+1} \leq$$

$$\leq z^i(1-\tau_y)w_t + b_t^{j>j^*} + a_t + p_{t-1}^h(1-\phi)h_t + (1-\tau_y)r_t^a a_t - \delta_h p_t^h(1-\phi)h_t + (p_t^h - p_{t-1}^h)(1-\phi)h_t$$

Voluntary Equity

In order to compute the equilibrium of the model, it is convenient to reformulate the household problem. Define voluntary equity as the wealth held less the proportional amount of land, $y_t^j \equiv a_t^j + p_{t-1}^h(1-\phi)h_t^j$. So:

$$c_t + r_t^f p_t^h f_t + y_{t+1} \leq$$

$$\leq z^i(1-\tau_y)w_t + b_t^{j>j^*} + y_t + (1-\tau_y)r_t^a a_t - \delta_h p_t^h(1-\phi)h_t + (p_t^h - p_{t-1}^h)(1-\phi)h_t$$

Where the term $(p_t^h - p_{t-1}^h)(1-\phi)h_t$ refers to the capital gains make by a household because of a change in housing prices from one period to the next.

The Borrowing Constraint

The borrowing constraint is:

$$a_{t+1} \geq -(1-\gamma_t)p_t^h h_{t+1}$$

which, making use of the definition for voluntary equity, can be written in the following way:

$$y_{t+1} + p_t^h \phi h_{t+1} \geq \gamma_t p_t^h h_{t+1}$$

becoming a constraint on next period's net worth:

$$y_{t+1} \geq (\gamma_t - \phi)p_t^h h_{t+1}$$

Solution Method

I follow closely the solution method from [43]. The state variables for the household problem are the earnings process, the quintile to which households belong to, and voluntary equity, $\{z^j, i, y_t^j\}$. With this reformulation, I deal with one state. This greatly simplifies the problem imposed by the endogenous liquidity constraint in the solution of the household problem.

The household problem can be broken down into intra-period and inter-temporal decisions. The inter-temporal decision consists of choosing the amount of savings to carry over to the next period. Once the inter-temporal decision is made, households choose the amount of composite goods and housing services to consume during the current period, as well as the composition of savings carried over from the previous period.

This possibility derives from the fact that only one state variable is needed to describe the situation of an age-j individual with productivity level z_j. This state variable is todays net worth, or alternatively yesterdays savings. Without uncertainty, the composition of todays savings between different assets is irrelevant since the same composition will result whether the decision is made today or tomorrow. Hence, the only information needed as an individual enters a period is the total amount of savings carried over from the previous period, as opposed its composition between financial assets and housing. In other words, todays amount of savings is chosen knowing that its composition will be optimized tomorrow.

These points become obvious in the following recursive formulation of the households problem. Let $v_t^j\left(y_t; i\right)$ denote the value of behaving optimally from period j until period J for an individual who enters period j with net worth y_t, productivity level z, and belonging to quintile i, in each period of time t. Given a net worth position at age j; a household chooses next periods net worth to maximize total future discounted utility. The value function of an age-j individual is defined as:

$$v_t^j\left(y_t; i\right) \equiv \max_{\left\{y_{t+1}^{j+1} \in \Gamma\right\}} \left\{G^j(y_t, y_{t+1}; i) + \beta v_{t+1}^{j+1}\left(y_{t+1}; i\right)\right\}$$

where Γ is the feasible set from which tomorrows net worth is chosen. The return function of an age-j individual, G^j; is defined as the maximum utility level a household can achieve given todays and tomorrows level of net worth. In other words, the return function is that which solves the following intra-temporal problem:

$$G^j(y_t, y_{t+1}; i) \equiv \max_{\left\{c_t^j, x_t^j, f_t^j, h_t^j, a_t^j\right\}} \{u(c_t, x_t)\}$$

$$s.t. \quad c_t + r_t^f p_t^h f_t + y_{t+1} + \delta_h p_t^h (1-\phi) h_t \leq$$

$$\leq z^i(1-\tau_y)w_t + b_t^{j>j^*} + y_t + (1-\tau_y)r_t^a a_t + (p_t^h - p_{t-1}^h)(1-\phi)h_t$$

$$y_t = a_t + p_{t-1}^h(1-\phi)h_t$$

$$x_t = f_t + h_t$$

$$y_t \geq (\gamma_{t-1} - \phi)p_{t-1}^h h_t$$

$$h_t \geq \underline{\mathrm{h}} \ \textit{otherwise} \ h_t = 0$$

For the results presented in this paper, I use 200 grid points for voluntary equity and linear interpolation in order to get more accuracy (the grid points are not equally space to maximize efficiency). Households in each quintile are born with zero financial assets ($a_t^1 = 0 \quad \forall i, \forall t$) and zero housing stock ($h_t^1 = 0 \quad \forall i, \forall t$).

Different Households

This economy will have three types of households each one solving her following problem.

Renters: Households with not enough net worth to buy the minimum house size are forced to rent, or some households would prefer to save more time to attain the desired level of owned housing by renting some periods before buying a house. In this case, they solve the following problem:

$$G(y_t, y_{t+1}; i) = \max_{\{c_t^j, f_t^j, a_t^j\}} \{u(c_t, f_t)\}$$

$$s.t. \quad c_t + r_t^f p_t^h f_t + y_{t+1} \leq$$

$$\leq z^i(1-\tau_y)w_t + b_t^{j>j^*} + y_t + (1-\tau_y)r_t^a a_t$$

$$y_t = a_t$$

$$y_t \geq 0$$

Home owners: Households with enough net worth to access to a house bigger than the minimum house size solve:

$$G^j(y_t, y_{t+1}; i) = \max_{\{c_t^j, h_t^j, a_t^j\}} \{u(c_t, h_t)\}$$

$$s.t. \quad c_t + y_{t+1} + \delta_h p_t^h (1-\phi) h_t \leq$$

$$\leq z^i (1-\tau_y) w_t + b_t^{j>j^*} + y_t + (1-\tau_y) r_t^a a_t + (p_t^h - p_{t-1}^h)(1-\phi) h_t$$

$$y_t = a_t + p_{t-1}^h (1-\phi) h_t$$

$$y_t \geq (\gamma_{t-1} - \phi) p_{t-1}^h h_t$$

$$h_t > \underline{\mathrm{h}}$$

Households in the margin (Cooperatives): There are some households with enough resources to buy the minimum house size and there would be constrained by this election. Here I make an assumption by allowing these households to make a convex combination between the minimum house size and the amount of housing services they would rent. The problem with the non-convexity of the minimum house size is that, along the transition and for the calibrated model, I always find some individuals jumping from owning the minimum house size to renting making impossible to clear the housing market. This happens for a very small fraction of individuals and could be solved by some others techniques as linear interpolation in ages. The existence of the minimum house size is key in this model since I do not have adjustment costs in housing capital and I want to model the homeownership rate. In my model, without a minimum house size, all individuals would own a small fraction of housing capital in all periods but the first one, in which they have zero assets by assumption. Since saving in a house has preference tax treatment and allows households to get credit, it is always preferred to renting. Both assumptions are in line with evidence.

By assuming that households can do a convex combination between renting and owning the minimum house, I can solve the problem of cleaning the housing market and have a realistic homeownership rate in the economy. I did some comparisons between the answer of the model with this assumption and without it (in a different calibrated model) and the answer is virtually the same.

The problem I solved for these households is this:

$$G^j(y_t, y_{t+1}; i) = \max_{\{c_t^j, x_t^j, q_t^j, f_t^j, h_t^j, a_t^j\}} \{u(c_t, x_t)\}$$

$$s.t. \quad c_t + r_t^f p_t^h q_t f_t + y_{t+1} + \delta_h p_t^h (1-\phi)(1-q_t)h_t \leq$$

$$\leq z^i(1-\tau_y)w_t + b_t^{j>j^*} + y_t + (1-\tau_y)r_t^a a_t + (p_t^h - p_{t-1}^h)(1-\phi)(1-q_t)h_t$$

$$y_t = a_t + p_{t-1}^h(1-\phi)(1-q_t)h_t$$

$$x_t = q_t f_t + (1-q_t)h_t$$

$$y_t \geq (\gamma_{t-1} - \phi)p_{t-1}^h(1-q_t)h_t$$

$$h_t = \underline{\mathrm{h}}$$

No more households in the economy will do a convex combination of this kind if it is not with the minimum house size. The reason is that they would never be indifferent between owning and renting in other cases different from the minimum house size.

An intuition for this problem would be to consider it as cooperatives, i.e. that some households, belonging to the same age and quintile, were allowed to establish a cooperative. Then, only some of them would live in the house, while the others would rent. However, they can use this house as a collateral for credit in the capital markets.

An alternative interpretation can be that households deposit their savings in a financial intermediary and that the probability of buying a house depends on the fraction of the downpayment deposited. If a household deposits half of the required downpayment to buy a house, then the household maybe allowed to buy a house with probability one half. If the household does not win the lottery, he does not lose his assets. Next period he will make a new deposit and get a new chance to buy a house.

Appendix A.2: Stationary Competitive Equilibrium

Denote $q = \{a, h, i\}$, q ∈ Q.

Definition *A* ***stationary competitive equilibrium*** *for a given government policy, τ_y, and downpayment requirement, γ, is a collection of relative prices $\left\{p^h, p^s, p^l, r^f, r, w\right\}$, a collection of functions for the household problem $\left\{v^j(q), c^j(q), f^j(q), h^j(q), a^j(q)\right\}$, an age-dependent measure of agents type, $\lambda_j(q)$, a value function for financial institutions $\Psi(F, B, A, K)$, and aggregate quantities for the whole economy $\left\{Y^c, Y^h, Y^s, X^s, L, K^c, K^s, N^c, N^s, F, B, A\right\}$ such that:*

1. *Inputs are priced competitively every period.*
2. *Given τ_y, γ and prices, the functions $\left\{v^j(q), c^j(q), f^j(q), h^j(q), a^j(q)\right\}$ solve the dynamic program from the household problem.*
3. *Given prices and the function $\Psi(F, B, A, K)$, $\{F', B', A', K'\}$, solves the financial institutions' problem.*
4. *Individual and aggregate decisions are consistent: $C = \sum_{j=1}^{J} \int_Q c^j d\lambda_j(q)$, $H = \sum_{j=1}^{J} \int_Q h^j d\lambda_j(q)$, $F = \sum_{j=1}^{J} \int_Q f^j d\lambda_j(q)$, $A = \sum_{j=1}^{J} \int_Q a^j d\lambda_j(q)$.*
5. *The government maintains a balanced budget:*
$$G + b = \sum_{j=1}^{J} \int_Q \left[\tau_y w z^j + \tau_y r a^j\right] d\lambda_j(q)$$
where $b = \sum_{j=1}^{J} \int_Q b^j d\lambda_j(q) = \tau_y w \overline{N}$.
6. *Labor market clears: $N^c + N^s = \overline{N}$.*
7. *Capital market clears: $K^c + K^s = K$.*
8. *Land market clears: $L = \overline{L}$.*
9. *Residential structures market clears: $X^s = Y^s$.*
10. *Housing market clears:*
$$Y^h = X^h + X^f$$
where $X^h = \delta_h H$, and $X^f = \delta_f F$.
11. *Trade balance is determined:*
$$TB = Y^c - C - X^k - G$$
where $X^k = \delta_k K$.

12. Net foreign asset position is determined:

$$B = -\left(\frac{TB}{r}\right)$$

Appendix B

Appendix to Chapter 2

Appendix B.1: The Perpetual Inventory Method

Ivie-BBVA reports data for capital stock but excluding residential capital stock. So, I proceed by using the data from Ivie-BBVA for the stock equipment. I compute the value for the depreciation of equipment from this series, given investment in equipment, and I get a value of $\delta_E = 0.105$.

For structures I proceed as follows: since I have the capital stock for equipment K_t^E, and the depreciation rate δ_E, I can subtract the depreciation of equipment $\delta_E K_t^E$ from the consumption of fixed capital from national accounts, δK_t, since they are in nominal terms, and obtain the depreciation coming from structures: $\delta_S K_t^S = \delta K_t - \delta_E K_t^E$, and thus I am able to apply the Perpetual Inventory Method for structures.

The numeraire is the non-durable consumption good. As a result, GDP in the data must be deflated by the non-durables consumption deflator, rather than the GDP deflator as in the one-sector environment.

Here the equations will be:

$$K_{t+1}^S = (1 - \delta_S) K_t^S + I_t^S, \tag{I}$$

where I_t^S is real investment,

$$\frac{1}{15} \sum_{t=1980}^{1994} \frac{\delta_S q_t^S K_t^S}{\tilde{Y}_t} = 0.0628, \tag{II}$$

and:

$$\frac{q_{1980}K^S_{1980}}{\tilde{Y}_{1980}} = \frac{1}{14}\sum_{t=1981}^{1994}\frac{q^S_t K^S_t}{\tilde{Y}t}, \tag{III}$$

where,

$$\tilde{Y}_t = C_t + q^E_t I^E_t + q^S_t I^S_t,$$

is GDP in current prices deflated by non-durables consumption deflator.

The system of equations (I)-(III) allows me to use data on structures, I^S_t, to solve for the sequence of structures stock and for the depreciation rate, δ_S. There are 29 unknowns: $\bar{K}^S_{1980}$, δ_S, and K^S_{1981}, K^S_{1982},..., K^S_{2007}, in 29 equations: (I), where $t = 1980, 1981, ..., 2006$, (II), and (III). Solving this system of equations, I obtain the sequence of structures stock and a calibrated value for depreciation, $\delta_S = 0.019$.

Appendix B.2: The Stock of Durables

From data on consumption durables it is possible to get the stock of consumption durables. Following [81] I make the assumption that there is a balanced growth path in 1980 to calculate the stock of consumption durables this year in this form:

$$\frac{S_d}{K} = \frac{C_d}{I} * \frac{(g+n+\delta)}{(g+n+\delta_d)}$$

where S_d is the stock of durables, C_d, is consumption durables, and δ_d, is the depreciation rate for durables. I pick the value for $\delta_d = 0.21$ from [22]. I get the value for the stock of durables in 1980. Then I apply the law of motion to get the series. Income of durables is obtained since it is possible to get the interest rate from the capital stock, its depreciation rate and the income of capital:

$$Y_d = (\delta_d + i) * S_d$$

Appendix B.3: Computational Algorithm

I use the method employed in [20]. Choosing $K^E_{T_0+1}, K^E_{T_0+2}, ..., K^E_{T_1}$, $K^S_{T_0+1}, K^S_{T_0+2}, ..., K^S_{T_1}$, and $L_{T_0}, L_{T_0+1}, ..., L_{T_1}$ to satisfy:

$$(1-\alpha_E-\alpha_S)Z_t(K^E_t)^{\alpha_E}(K^S_t)^{\alpha_S}L_{t+1}^{-\alpha_E-\alpha_S}(\bar{h}N_t - L_t) = \frac{1-\gamma}{\gamma}C_t, \tag{I}$$

$$\frac{C_{t+1}}{C_t} = \frac{1}{q^E_t}\beta((1-\delta_E)q^E_{t+1} + \alpha_E Z_{t+1}(K^E_{t+1})^{\alpha_E-1}(K^S_{t+1})^{\alpha_S}L_{t+1}^{1-\alpha_E-\alpha_S}), \tag{II}$$

$$\frac{C_{t+1}}{C_t} = \frac{1}{q^S_t}\beta((1-\delta_S)q^S_{t+1} + (1-\tau^S_{t+1})\alpha_S Z_{t+1}(K^E_{t+1})^{\alpha_E}(K^S_{t+1})^{\alpha_S-1}L_{t+1}^{1-\alpha_E-\alpha_S}), \tag{III}$$

where:

$$C_t = Z_t(K^E_t)^{\alpha_E}(K^S_t)^{\alpha_S}L_t^{1-\alpha_E-\alpha_S} - q^E_t K^E_{t+1} + (1-\delta_E)q^E_t K^E_t - q^S_t K^S_{t+1} + (1-\delta_S)q^S_t K^S_t,$$

where (I) is for $t = T_0, T_0+1, ..., T_1$, (II) and (III) for $t = T_0, T_0+1, ..., T_1-1$, and where $K^E_{T_1+1} = gnK^E_{T_1}$, and $K^S_{T_1+1} = gnK^S_{T_1}$.

This problem requires solving $3(T_1-T_0)-2$ equations in $3(T_1-T_0)-2$ unknowns. The MATLAB program uses Newton's method to solve the system of equations. Define the stacked vector of variables $x = [K^E_{T_0+1}, K^E_{T_0+2}, ..., K^E_{T_1}, K^S_{T_0+1}, K^S_{T_0+2}, ..., K^S_{T_1}, L_{T_0}, L_{T_0+1}, ..., L_{T_1}]'$ and arrange the system of equations so that they are of the form $f(x) = \bar{0}$, where $\bar{0}$ is a $3(T_1-T_0)-2$ vector of zeros. The algorithm involves making an initial guess at the variables, x^0, and updating the guess by $x^{i+1} = x^i - Df(x^i)^{-1}f(x^i)$, where $Df(x^i)$ is the matrix of partial derivatives of $f(x)$ evaluated at x^i. The system of equations does not have closed-form expressions for the partial derivatives needed to compute $Df(x^i)$, and so the derivatives have to be evaluated numerically. A solution is obtained when the function, evaluated at the new iterate of x, has a maximum error less than some value ε, where ε is a small number. Although this method of solving a system of nonlinear equations can converge to a solution quickly, this method is not globally convergent and can become stuck away from a zero of $f(x)$ or may not converge at all. The initial guess, x^0, is important. Further details on the implementation of Newton's method can be found in [23].

To increase the probability of the algorithm converging to the correct answer, I solve a sequence of models, beginning with a simple version of the model, which I know how to solve, and progressing to the model that we would like to solve. The first model I solve is the one in which TFP, relative price of equipment, wedge in structures, population, and available hours are constant and equal to their average values from 1985 to 2007. The solution to this problem is relatively easy to find. The next model takes TFP, relative price of equipment, wedge in structures, population, and available hours, to be convex combinations of the constant values used in the initial model and the actual values of TFP, relative price of equipment, wedge in structures, population, and available hours, from the data. Let λ be the weight on the constant values, so that $(1-\lambda)$ is the weight on the values from the data. The algorithm requires repeatedly decrementing λ and solving the resulting model, each time using the solution to the model before it as the initial guess. The algorithm proceeds until it solves the case in which $\lambda = 0$, which corresponds to the model whose solution I desire. If the value of investment becomes negative in some period t, I replace the corresponding equation (II) or (III) with equations:

$$K_{t+1}^{E} = (1-\delta_E)K_t^{E}, \tag{IV}$$

$$K_{t+1}^{S} = (1-\delta_S)K_t^{S}, \tag{V}$$

respectively. As I change λ, I check that the inequalities:

$$\frac{C_{t+1}}{C_t} \geq \frac{1}{q_t^E}\beta((1-\delta_E)q_{t+1}^E + \alpha_E Z_{t+1}(K_{t+1}^E)^{\alpha_E-1}(K_{t+1}^S)^{\alpha_S} L_{t+1}^{1-\alpha_E-\alpha_S}),$$

$$\frac{C_{t+1}}{C_t} \geq \frac{1}{q_t^S}\beta((1-\delta_S)q_{t+1}^S + (1-\tau_{t+1}^S)\alpha_S Z_{t+1}(K_{t+1}^E)^{\alpha_E}(K_{t+1}^S)^{\alpha_S-1} L_{t+1}^{1-\alpha_E-\alpha_S}),$$

hold. If it do not, I replace the corresponding (IV) with (II), or (V) with (III), respectively.

Appendix B.4: The One Sector Growth Model

Description of the Model and Equilibrium

The standard one sector growth model features a representative household that chooses paths of consumption, leisure, and investment in order to maximize utility. The household maximizes the following utility function:

$$\sum_{t=T_0}^{\infty} \beta^t \left[\gamma \log C_t + (1-\gamma) \log(\overline{h} N_t - L_t) \right], \tag{a}$$

subject to a sequence of budget constraints:

$$C_t + K_{t+1} - (1-\delta)K_t = w_t L_t + r_t K_t, \tag{b}$$

nonnegativity constraints on C_t, and $I_t = K_{t+1} - (1-\delta)K_t$, and a constraint on the initial stock of capital, $\overline{K}_{T_0}$. In the utility function, the parameter β, $0 < \beta < 1$, is the discount factor and the parameter γ, $0 < \gamma < 1$, is the consumption share. C_t, is consumption, K_t, is the capital stock, L_t, is hours worked, w_t, is the wage rate, r_t, is the rental rate, and δ, $0 < \delta < 1$, is the depreciation rate. The total number of hours available for work is $\overline{h} N_t$, where N_t is the working-age population and $\overline{h}$ is the number of hours available for market work. I specify $\overline{h}$ as 100 hours per week. One period of time is a year.

Firms operate in a perfectly competitive market, using a technology with constant returns to scale, which I assume to be Cobb-Douglas:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{c}$$

where Y_t denotes total output, A_t is total factor productivity (TFP), and α, $0 < \alpha < 1$, is the capital share. Factor prices can be derived from the condition that firms earn zero profits:

$$w_t = (1-\alpha) A_t K_{t_t}^{\alpha} L_t^{-\alpha}, \tag{d}$$

$$r_t = \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha}. \tag{e}$$

Given that the current period's output is divided between consumption and investment give the feasibility constraint:

$$C_t + K_{t+1} - (1-\delta)K_t = A_t K_t^{\alpha} L_t^{1-\alpha}. \tag{f}$$

By taking first-order conditions of the household's problem I obtain:

$$w_t(\overline{h}N_t - L_t) = \frac{1-\gamma}{\gamma} C_t, \tag{g}$$

$$\frac{C_{t+1}}{C_t} = \beta(1 - \delta + r_{t+1}). \tag{h}$$

This two equations, (g) and (h), together with firm optimality conditions (d) and (e) and the feasibility condition (f), compose the system of equations that can be solved to find the equilibrium of the model. Also the transversality condition is given as:

$$\lim_{t\to\infty} \beta^t \frac{\gamma}{C_t} K_{t+1} = 0.$$

The model describe a representative household that chooses paths of consumption, leisure, and investment to maximize utility. The paths of TFP and population are exogenously given, and the agent has perfect foresight over their values. The model starts at $T_0 = 1985$ and let time run out to infinity.

Definition *Given sequences of productivity, A_t, working-age population, N_t, $t = T_0, T_0 + 1, ...$, and the initial capital stock, $\overline{K}_{T_0}$, an* ***equilibrium with one sector*** *is sequences of wages, w_t, interest rates, r_t, consumption, C_t, labor, L_t, and capital stocks, K_t, such that:*

1. *given the wages and interest rates, the representative household chooses consumption, labor, and capital to maximize the utility function (a) subject to the budget constraints (b), non-negativity constraints, and given $\overline{K}_{T_0}$;*
2. *wages and interest rates, and labor and capital choices by firms, satisfy the cost minimization and zero profit conditions, (d) and (e); and*
3. *consumption, labor, and capital satisfy the feasibility condition (f).*

The Perpetual Inventory Method

Standard national accounts of Spain do not report a series for the capital stock, so I have to construct such a series using the data on investment. I construct these series using the law of motion for capital in the model:

$$K_{t+1} = (1-\delta)K_t + I_t. \tag{I}$$

This commonly used procedure for calculating a capital stock is referred to as the perpetual inventory method. The inputs necessary to construct the capital stock series are a capital stock at the beginning of the investment series and a value for the constant depreciation rate, δ. The value of δ is chosen to be consistent with the average ratio of depreciation to GDP observed in the data over the data period used for calibration purposes. I find that the ratio of depreciation to GDP over the period 1980-1994 is

$$\frac{1}{15}\sum_{t=1980}^{1994}\frac{\delta K_t}{Y_t} = 0.1139 \tag{II}$$

Without explicit data on the capital stock at the beginning of the investment series, I follow [20] in adopting a more or less arbitrary rule. The capital-output ratio of the initial period should match the average capital-output ratio over some reference period. Here I choose the capital stock so that the capital-output ratio in 1980 matches its average over 1981-94:

$$\frac{K_{1980}}{Y_{1980}} = \frac{1}{14}\sum_{t=1981}^{1994}\frac{K_t}{Yt} \tag{III}$$

The system of equations (I)-(III) allows me to use data on investment, I_t, to solve for the sequence of capital stocks and for the depreciation rate, δ. There are 29 unknowns: $\bar{K}_{1980}$, δ, and K_{1981}, K_{1982},..., K_{2007}, in 29 equations: (I), where $t = 1980, 1981, ..., 2006$, (II), and (III). Solving this system of equations, we obtain the sequence of capital stocks and a calibrated value for depreciation, $\delta = 0.037$.

Measured TFP and Calibration

Using the procedure outlined by [22] it can be done. The capital share will be the flow of services of capital over the GDP of the economy. The value for the share of capital obtained is $\alpha = 0.36$.

Once I have obtained measures for output, investment, capital stock and hours worked, and have calibrated the capital share parameter, I compute TFP as:

$$A_t = \frac{Y_t}{K_t^{\alpha} L_t^{1-\alpha}}.$$

where, in this equation, output and capital stock series are both deflated by the GDP deflator.

In addition to the exogenous paths for productivity and population, and in addition to he calibration of δ and α that I did above, I need to specify the parameters β and γ.

To calibrate a value for β I use equations (h), (f) and (e) to write:

$$\beta = \frac{C_{t+1}}{C_t(1 - \delta + \alpha \frac{Y_{t+1}}{K_{t+1}})}.$$

With values for α and δ, data on capital, output, and consumption, I can compute β for each period and take the average over the period 1990-2007. In this case $\beta = 0.961$.

To calibrate a value for γ I use equations (g) and (d) to write:

$$\frac{1-\gamma}{\gamma} = (1-\alpha)\frac{Y_t}{L_t}\frac{(\bar{h}N_t - L_t)}{C_t}.$$

With the value for α, and data on consumption, hours worked, population, and output it is found a value for $\gamma = 0.203$ for the same period 1990-2007.

Appendix B.5: TFP Contribution of Capital Goods with Different Factor Shares

Given the production functions with different factor shares, and, as before, assuming perfect competition, the growth rate of the relative price of structures is defined by:

$$\theta_{1/q^S} = \widehat{\left(\frac{p_t^S}{p_t^C}\right)} = \widehat{\left(\frac{A_t^C}{A_t^S}\right)} + (\alpha_S - \gamma_S)\widehat{\left(\frac{K_t^{SS}}{L_t^S}\right)} + (\alpha_E - \gamma_E)\widehat{\left(\frac{K_t^{SE}}{L_t^S}\right)}$$

taking data for 1995-2007, since this years are the years of the high increase in prices, from BBVA-Ivie for the ratios $\frac{K_t}{L_t}$,

$$\widehat{\left(\frac{K_t^{SS}}{L_t^S}\right)} = -3.64\%; \text{ and } \widehat{\left(\frac{K_t^{SE}}{L_t^S}\right)} = +4.88\%$$

it can be seen that the values are similar in absolute value. By Herrendorf and Valentinyi (2007) for US, and claiming that the differences between factor shares in US and Spain would not be so different, we know: $\alpha_S + \alpha_E > \gamma_S + \gamma_E \rightarrow \alpha_S - \gamma_S = 0.11$ and $\alpha_E - \gamma_E = 0.02$. Given the small values for these differences I can conclude that probably the equal factor shares assumption is not so distorting, and If we take those numbers seriously the measure given under the assumption of equal factor shares would be a lower bound for the negative contribution to aggregate TFP.

For the case of equipment and from [54] the contribution would be greater if equipment sector is labor intensive, and from [52] equipment sector is labor intensive for the US.

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